

# undersea technology

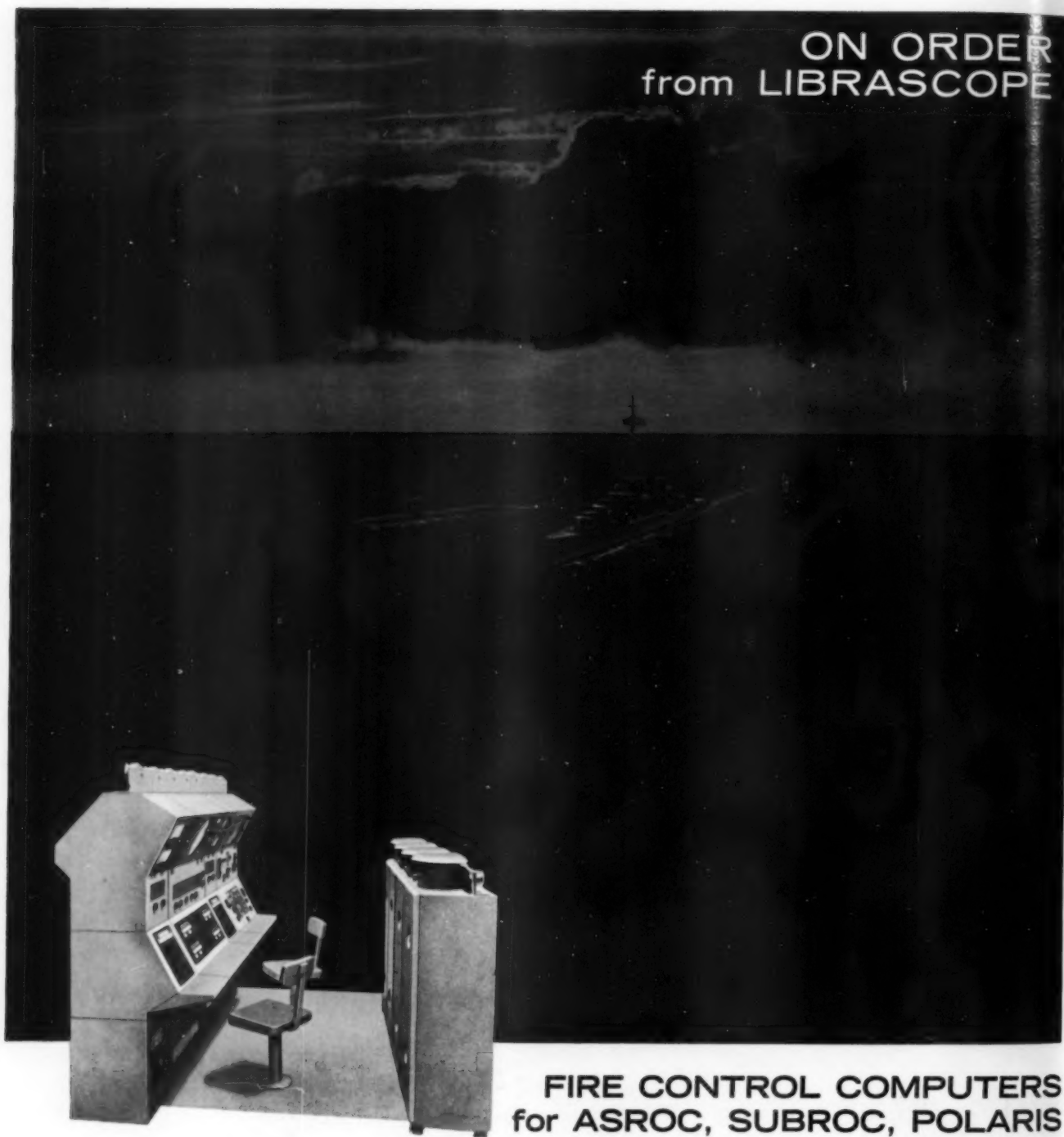
including underwater engineering

September/October  
Volume 2, No. 1



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# undersea technology

**COVER:** In fanned array on UST's cover is a series of high-speed photographs of a model missile making a high-speed water exit in a test tank at Naval Ordnance Test Station, Pasadena Annex. This isn't any missile in particular, but is part of a fundamental program being conducted by the Navy in order to gain basic design knowledge. Significantly, Navy anticipates that a greater and greater proportion of its future armament will be underwater launched, and at higher and higher speeds (see submarine of 1970, p. 15). Cover story starts on page 24.

Vol. 2      Number 5  
September/October 1961

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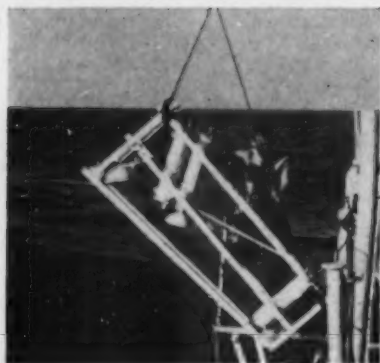
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pp. 24-26, Official Photographs, U.S. Navy; pp. 27-30, Official Photographs, U.S. Navy.



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## editorial:

# "I WILL SINK YOU!"

СООБЩЕНИЕ ТАСС

Как стало известно, за последний период времени имел место ряд нарушений морской государственной границы Союза ССР иностранными подводными лодками. При этом иностранные подводные лодки входили в советские территориальные воды в подводном положении, производили маневрирование и вели наблюдение с целью разведки.

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В связи с этим Правительством Союза ССР даны инструкции Министерству обороны СССР впредь при обнаружении в советских территориальных водах иностранных подводных лодок, нарушивших государственную границу Союза ССР и находящихся в подводном положении, — принимать меры к уничтожению нарушителя.

In November, 1956, at a diplomatic reception in Moscow, Soviet Premier Nikita Krushchev boasted confidently: "History is on our side. I will bury you!", speaking about the West in general and the U.S. in particular. Reproduced above are the operative paragraphs of a Tass release dated August 29, 1961. They say, respectively: "Lately foreign submarines have been detected in Soviet territorial waters . . . the USSR has instructed the Ministry of Defense of the USSR to destroy such violators . . ."

In September 1959, at the National Press Club in Washington, D.C., Krushchev claimed that in 1956 he was speaking economically. There can be no such interpretation of the Tass release, which came out a good ten days after we had reported and written "The Invisible War" on page 14, wherein we point out the danger of a real hot war breaking out in the ocean's depths.

Tass lays the propaganda groundwork for the Kremlin's loud protestations of violated sovereignty—should they ever be charged with sinking one of our submarines. The limits of territorial waters have nothing to do with it. To Russia this means within POLARIS missile range of the Soviet land mass. The Tass release proves the Soviets are preparing for just such warfare as we outline in "The Invisible War." If Reds claim "within Soviet territorial waters," who is to prove otherwise?

Everything indicates that guerilla warfare tactics will soon be employed on a deadly scale in the underseas realm. This will sorely try our performance in the diplomatic arena and will put our operational technologies to a severe and continuing test.

Just when the Russians will first use the Tass announcement as moral justification to the rest of the world, not even Krushchev knows. But even before this happens we must take major steps to improve our underseas capabilities—to not only keep our present lead, if indeed we still have it, but, imperatively, to widen it. SAC bombers and ICBMs may wait poised in readiness for 20 years. The Invisible War may start at any moment.



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\*President John F. Kennedy's  
State of the Union message,  
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## capital report E. E. Halmos, Jr.

A report on the feasibility and costs of sea-launch of scientific vehicles is due from National Aeronautics & Space Administration within the next three months. It will be the result of a year-long study by NASA, Navy, Air Force, and Army, and reflects a growing interest in the possibility of some sort of mobile platforms as a means of obtaining equatorial orbits (for instance) and saving money. A successful scheme for launching heavy space probes at sea would have major defense implications—it would immediately open the way for launch sites that would be relatively cheap, almost impregnable from attack. And similar installations could also be made in the Great Lakes and deeper river and lakes throughout the U.S.

It is interesting that the study has been pushed, even though NASA told the House Committee on Science and Astronautics, in hearings last May, that it had "no present requirements for the use of ships, drydocks or associated platforms to support vehicle programs now in force." In addition to its own program, NASA has been "exploring the thinking" of at least nine major engineering and construction organizations that have advanced schemes for such a sea-launch capability.

NASA's interest is purely scientific—and its somewhat lukewarm approach to the subject last May is tied to the fact that scientists feel that the desired equatorial orbit can now be achieved (by dog-legging the course of a rocket) at a cost small enough to make an actual equatorial launch site uneconomic.

But the interest of the armed services has been increasing over the past several months, and it is known that at least two major schemes for such a launch operation have been proposed—right down to drawings and detailed cost estimates. Basically, the schemes are keyed to a Texas-tower type mobile platform or group of platforms, that could be towed to almost any desired site in the ocean, lower huge "legs" to the bottom and be packed out of the water to provide a firm, fixed firing platform, then be moved—if need be—to another spot after launch.

Advantages are obvious—even beside the fact that the platforms would provide a poor target for an enemy, since they could be shifted about. Principal advantage, would be that all of the highly skilled work that goes into such a launch complex could be done at U. S. bases on the mainland, and then the entire installation—including power-plants, instrumentation, the missile itself, and the necessary crews—could be towed anywhere. There is little question that such a procedure would be far cheaper than an attempt to set up a site on some distant island, with the attendant problem of shipping equipment, materials, technicians, housing and other things to such a distant spot.

In the wake of government activity to get a real Oceanography program underway, has come the announcement of significant undersea developments by several major industrial concerns.

Not to be outdone by industry, government agencies are also pushing their own sea technology work. Navy's Bureau of Weapons and the National Bureau of Standards have already dropped NOMAD I into the waters of the Gulf of Mexico, about 300 miles south of New Orleans, to report on formation of hurricanes. Looking like assembly of four big pressure-cookers, NOMAD I does the work of a weatherman under conditions impossible for humans, transmitting at six-hour intervals (and every hour during high winds) weather data which its gear has measured and coded: Air temperature, water temperature, barometric pressure, wind speed and direction, and the direction of surface ocean currents. The rig is moored to the bottom by a 15,000-ft anchor chain, uses variable-tone pulse signals and international Morse code. An experimental water-immersed silicon solar battery, and batteries recharged by wind-driven generators provide power.

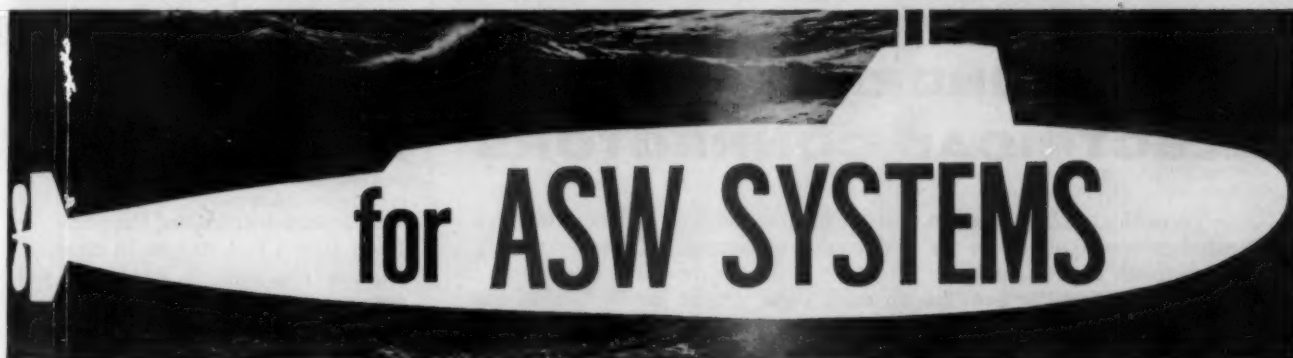
Any experimentation with the control of weather is a good idea—but it must be carefully controlled lest forces so huge as to be unimaginable be thrown out of kilter. That's the judgment of the National Science Foundation, in a report to Congress on the possibilities of weather control.

NSF pointed out the nature of the forces that weather controllers would deal with: The snowstorm that hit New York City last February was estimated to have dumped more than 40 million tons of snow—enough that the energy of 120 nuclear bombs would have been required if that one snowfall were melted in a continuous operation. "It is possible," said NSF, "that man may be able to exercise control of the weather—and means to do so should be explored. But the dangers inherent in such an attempt, and the enormous forces involved, should be kept in mind."

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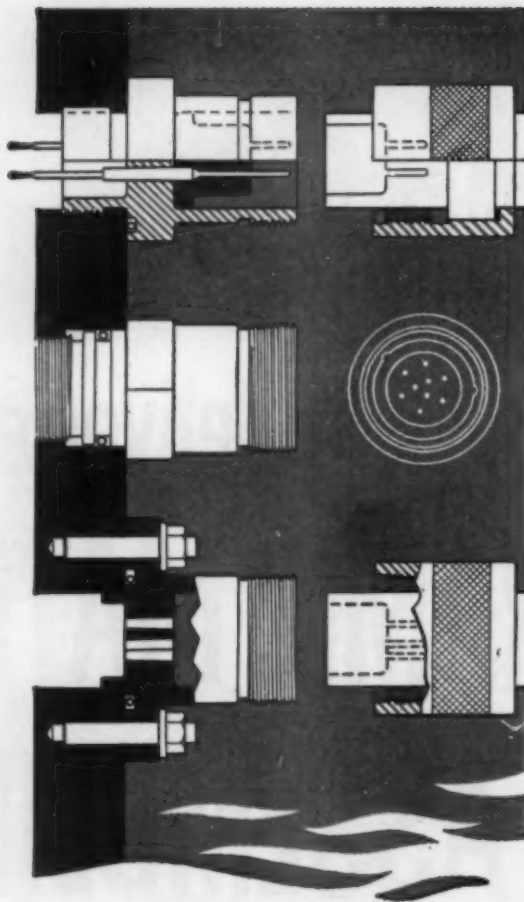
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## **H. E. COOK JOINS ADVISORY BOARD**



Undersea Technology magazine is happy to welcome to its Board of Advisors Mr. Herbert A. Cook, President and founder of Airpax Electronics, Inc. In addition to his presidential duties, he participates in the engineering activities of the organization, lectures, and conducts symposia on engineering subjects, and has authored technical books on electronic systems and components. He is recognized as a leading authority on contact modulators due to his pioneering work and success in the perfection of these devices.

Graduating from the University of Iowa with a B.S. degree in electrical engineering, he was associated with several large organizations in various engineering capacities before forming his own company. His engineering experience includes design and development of complex electronic components, servo and telemetry systems, computers and radar networks. He has a number of inventions to his credit, holds several patents on electro-mechanical devices and has recently made application for a patent on a position servo feedback system.

With an interest in new and novel scientific endeavors, he has pursued the subject of oceanography for a number of years—a topic which is currently receiving wide-spread attention from the Department of Defense. Avocations include navigation, aviation, and astronomy. He is a member of IRE and all professional groups within the organization, and heads the Steering Committee of the Instrument Society of America's Marine Sciences Division.



TAGGART



SNYDER



BATES

## UST ENLARGES STAFF

It is with great pleasure we welcome three new members to our editorial staff—Mr. Robert Taggart, *Undersea Systems*; Mr. Robert M. Snyder, *Oceanography*; and Mr. Robert G. Bates, *West Coast Correspondent*.

Mr. Taggart, who graduated from Webb Institute of Naval Architecture in 1942 with a B.S. degree in Naval Architecture and Marine Engineering, served as a Naval Officer during World War II. Currently the head of Robert Taggart, Inc., he has a wide experience in marine science and technology having worked with the Maritime Commission, the Naval Research Laboratory, the Army Transportation Corps, the Bureau of Ships, and Reed Research, Inc. For a period of more than 15 years he has been engaged in a variety of projects involving research and development activities, model testing, and design, construction, and operation of model test and full scale trial instrumentation.

While with BuShips Noise, Shock, and Vibration Branch, Mr. Taggart planned and administered the ship noise control program which included noise reduction of machinery, particularly in submarines. Other tasks were the planning and development of two underwater acoustics ranges, preparation of operational requirements for ship noise control, and quieting of control spaces onboard naval vessels. At Reed Research, Inc. he was responsible for the company's experimental programs in hydrodynamics, ship structures, and acoustics.

Among his most recent accomplishments is the design of the dynamic ship positioning system for project MOHOLE (see UST Vol. 2, No. 3, May/June 1961, page 24.)

Mr. Taggart has published numerous reports, papers, and articles covering such subjects as side launching calculations, ship standardization and fuel economy trials, maneuvering trials, hull form studies, development of underwater acoustics facilities, noise reduction, ambient noise surveys, underwater missiles, and many more.

He is a licensed professional engineer in the District of Columbia and in Virginia, and belongs to a

series of professional organizations including the Society of Naval Architects and Marine Engineers, the American Institute of Physics, and the Acoustical Society of America.

Mr. Robert M. Snyder, a staff member of the Woods Hole Oceanographic Institution, graduated from Rensselaer Polytechnic Institute in 1959, majoring in physics. While at RPI he produced a senior thesis—*MACHINA REFLEXUS PRINCIPUS*—an electronic analog of the basic reflex arc, which earned him an election to The Society of The Sigma Xi.

Mr. Snyder was formerly a staff member of the American Miscellaneous Society (AMSOC). His work there included engineering buoy design, logging applications, and transponder tests onboard the *Sonar Queen*. During the entire Project MOHOLE drilling programs off La Jolla and Guadalupe Mr. Snyder was onboard the *Cuss-I* where he helped maintain the electronic equipment, and also took the first deep current velocity measurements ever made in the Pacific.

Mr. Robert G. Bates, our West Coast correspondent, has a broad background in journalism, particularly in the field of oceanography and associated marine sciences. As director of the Crescent Engineering and Research Co.'s Oceanic Division he initiated and had responsibility for the gathering and evaluation of information, editing, and publishing of *Crescent Oceanographic Bulletin*, a monthly publication abstracting international research and development information in the marine sciences and technology field. In this capacity Mr. Bates covered such areas as oceanographic exploration, marine biology, submarine geology, undersea photography, ordnance, as well as physical and chemical oceanography.

Through his work in the highly specialized field of marine scientific and technological reporting, Mr. Bates has initiated and maintained close personal relationships with technical and scientific personnel in educational institutions, private research groups, government agencies—military as well as civilian—and in the marine industry as a whole.

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## LATE NEWS

The largest and most far-reaching season of scientific research in the Antarctic for the U.S. is about to be launched. In October, close to 200 scientists will undertake research projects under \$5½ million in National Science Foundation grants. . . . **The origins and behavior of the mysterious sand waves** that intersect the coastline in many areas between Cape Hatteras and New York will soon be investigated by oceanographers as a result of a research grant award by the Coast and Geodetic Survey . . . **Proceedings of the first Inter-Agency Symposium** on Oceanography will be available to the public for \$5.00. This meeting was to inform industry of the needs and requirements for instrumentation in the field of Marine Sciences. Copies of the proceedings can be obtained from the Miller Columbian Reporting Service, 931 G. Street, N.W., Washington 1, D.C.

## OCEANOGRAPHY

New to the field of oceanography is Loral Electronics Corp., with the acquisition of an entire line of underwater vehicles, photographic equipment and related devices. They have also obtained the services of renowned French inventor, undersea explorer, and photographer, Dr. Dimitri Rebikoff. Along with Dr. Rebikoff come exclusive rights to a series of one- and two-man operated and remote controlled underwater vehicles that maneuver like aircraft and can carry men on missions of survey and exploration to the depths of the ocean.

Two prototype oceanographic systems are being developed for the Hydrographic Office, U.S. Navy, by Airpax Electronics, Inc. The systems include current direction measuring instruments and temperature sensors. Airpax has engineered a partially submerged temperature sensor system used for measurement just above and below the oceans surface. The aim is to predict climatic changes.

## ENVIRONMENTAL

An underwater launching facility for POLARIS missile testing was recently completed at the San Clemente Island Test Range of the Naval Ordnance Test Station. The device will be used in test firing missiles from various ocean depths. It consists of four separate movable steel spools, stacked on top of each other to form a tower, and anchored to pilings set in the ocean floor.

## SOUND

The first of a new generation of super-sonar equipment—appreciably increasing the range at which submarines can be detected—is being delivered to the Navy by Edo Corp. The important factor is its rated ability to penetrate the underwater thermal layers where temperature changes block or distort signals. This could be a major breakthrough in ASW.

“Sonar goes nuclear” could be the title of an article in the category of “—and other uses”, according to a new technique growing out of General Electric. The same kind of device used aboard ship to measure ocean depths is undergoing conversion to probe G.E.-operated Hanford nuclear reactors for vital test data. The sounding gear beams an instant and exact picture to an oscillograph screen showing what's inside the reactor process tubes. It is expected that the device will tie in with other testing equipment used to detect possible corrosion in the metal process tubes.

## NAVIGATION

A newly developed steering mechanism composed of swaged directional-control rods, manufactured by Bergen Wire Rope Co., will direct the Navy's latest ASW weapon—an unmanned helicopter—to its target. Designated the DSN-1, the helicopter is part of the DASH (Drone Anti-Submarine Helicopter) Weapons Systems. The unit represents a major advance in directional control for coaxial-type helicopters, making drone flights practical and accurate.

## PERSONALITIES

Dr. F. J. Weyl has been appointed Deputy Chief and Chief Scientist of the Office of Naval Research, and will replace Dr. Thomas J. Killian who has resigned to accept a position in private industry.

Dr. Weyl, presently Research Director, has been associated with ONR since 1947. In 1958 he became Director of the Naval Analysis Group of ONR, and the same year was appointed Research Director. The new Chief Scientist is the son of the internationally famous mathematician Professor Herman Weyl, who joined the Institute for Advanced Study at Princeton in 1933.

## RESEARCH

The feasibility of freezing a ship into an ice pack in the Arctic Ocean for a 3-year scientific research program is currently under study by the Navy's Bu/Ships. The lack of large land masses in the Arctic region prevent the establishment of any Antarctic-type base stations, so the ship would act as a floating “Little America”.

## MEETINGS

- Oct. 9-11 National Electronics Conference & Exhibit, Chicago
- Oct. 10-12 National Conference on Standards, Houston, Texas
- Oct. 30-Nov. 1—33rd Annual Radio Fall Meeting, Syracuse, N.Y.

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## LETTERS TO THE EDITOR

### Extra Copies

To The Editor:

Have an overjoyed group of DSD people here who would love a copy of July/August UST. Could you send me about 50 copies for their benefit and for file?

William A. Ternent  
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Defense Electronics Div.  
General Electric Co.

The 50 copies are en route.—Ed.

### Watch The ASNE Journal

To The Editor:

Permission is requested to reprint the article "UST Needs in Review" which appeared in the July/August 1961 issue. Full acknowledgment will be given as to the source and author.

If permission is granted, the article will probably appear in the November 1961 issue of the Journal of The American Society of Naval Engineers.

Joe W. Thornbury  
Assistant Secretary-Treasurer  
The American Society of Naval Engineers, Inc.

Permission granted.—Ed.

### From The Rose Bouquet

To The Editor:

I recently had the opportunity to read one of the issues of Undersea Technology and I was impressed with the material coverage. Belock Instrument Corporation is active in the underwater ordnance field with BuWeps in the field of torpedo components and also in the ASROC program.

It would be appreciated if the company could be included in your circulation to receive copies of Undersea Technology.

L. E. Troutman  
Assistant Chief Engineer  
Belock Instrument Corporation

To The Editor:

Enclosed herewith please find your subscription qualification form returned and completed.

In my dual capacity of Sales Manager, and Assistant Chief Engineer of this company, I find great use of UST. It will soon be directly responsible for the conception and production of a new civilian under-

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water device.

But even more important, perhaps, is a second use of UST. As a Naval Reserve Lieutenant, and Executive Officer of a Naval Reserve Division, I find that UST is a great training aid in A.S.W. matters, from a technical standpoint. It enables us to add that little extra which improves training, morale and overall interest in the Naval Reserve. As the Navy would say, "Well Done."

**Kenneth Grayson**

Hartman Marine Equipment Corp.

### To The Editor:

I would like to take this opportunity to express my high regard for the contribution your magazine is making in the field of oceanography in general. As a former Research Associate of the Woods Hole Oceanographic Institute, I feel I can testify to the difficulties this basic earth science has experienced in receiving the pressing recognition it must now, of necessity, deserve. The constant stress your publication is placing on the need for a greatly expanded research program in oceanography is indeed most gratifying.

**Dr. Charles E. Carver, Jr.**

Consultant, Undersea Weapons Engineering Defense Electronics Div. General Electric Co., and Associate Professor of Civil Engineering—University of Massachusetts, Amherst, Mass.

### No Back Issues

#### To The Editor:

Upon recently joining Acoustica Associates, Inc., as Director of Research, I have found that the company's library does not have copies of your publication prior to the May/June 1961 issue. Would it be possible to obtain from you copies of past issues to make our file complete?

I have found your publication to be most interesting and informative in the fields of Oceanography and Underwater Engineering and therefore, believe it is a necessary addition to our referenced material concerning the fields of ASW and Underwater Acoustics with which we are intimately concerned.

**Cameron Knox, Ph.D.**

Director of Research  
Acoustics Associates, Inc.

Many of our readers are requesting back issues of Undersea Technology magazine. We regret that due to the large demand for prior issues and the rapid increase in circulation, our supply of back issues is completely exhausted.—Ed.

# new u s i books

THE SEA AROUND US, by Rachel L. Carson, \$5.00. (Oxford University Press, 1961)

A short time ago, the Interagency Committee on Oceanography held their first symposium to acquaint industry with the needs and requirements for instrumentation to further conduct ocean research and surveys. In order to brief industry on oceanographic technology, the agency sent out a bibliography of suggested reading on the subject, along with the invitations. Among the seven books listed was the revised edition of Rachel Carson's THE SEA AROUND US. This all too short work (237 pp.) presents a history and a scientific study of the oceans with all the fascination of a Jules Verne novel. From the beginning to the end, commencing with the origins of the seas, the reader is subjected to an eddy of abyssmal arcana; he will explore hidden lands and witness the birth of an island. He will come to understand the interaction of the wind, the sun and the waters, and he will learn of the magnitude of wealth that lies within the deep.

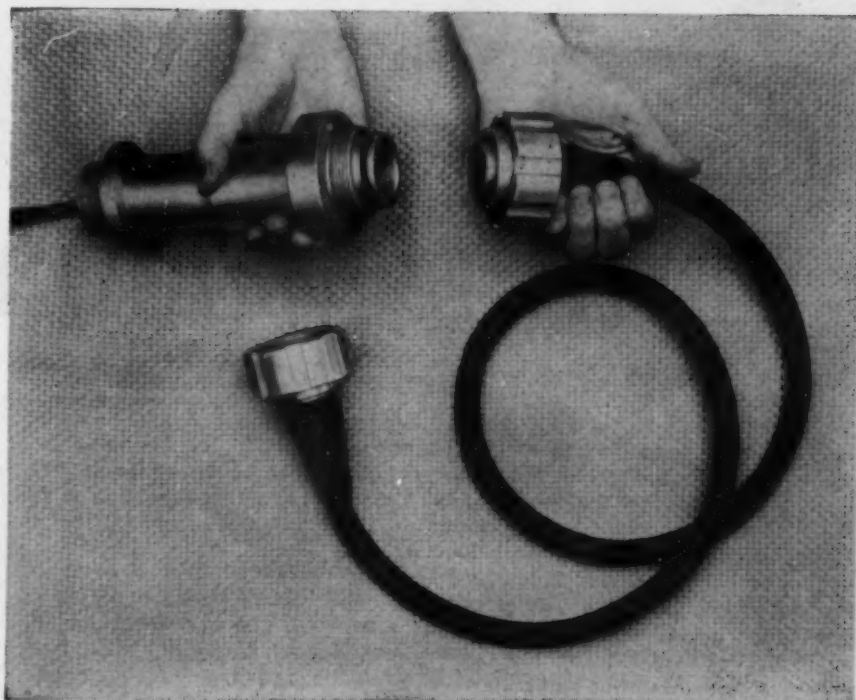
The revised edition includes an appendix to the original text with notes on the numerous achievements that have been made since the appearance of the first edition.

Miss Carson's literary ability coupled with scientific accuracy has resulted in a book that will enchant "everyone whose imagination has ever been touched by the magic and mystery of the sea. . . ."

SERVO ENGINEER'S HANDBOOK, Transicoil Div., Daystrom, Inc., \$3.00 (Fourth Printing, 1961)

This comprehensive guide to the application of servomechanisms deals with the usage of the individual components. Although the basic theory is presented, the overall treatment is practical rather than classical.

The first chapter deals with introductory material, covering theory, design and system evaluation. The next five chapters, the heart of the handbook, details the servo applications to generator, motors, synchros, gear trains and amplifiers. Chapter 7 highlights pertinency to complex electronic systems. The last chapter is a brief, but informative section on environmental testing of the servo units. A glossary of terms and a table of symbols, definitions and units of measurement are in appendices. A concise handbook for servo designers.



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# THE INVISIBLE WAR

By Seabrook Hull

The 68 days from November 15, 1960 until January 21, 1961 were some of the more uncomfortable in the history of the Office of the Chief of Naval Operations. This was the period of the first combat patrol by SS(B)N 598, the POLARIS missile-carrying submarine, GEORGE WASHINGTON. Staff of the CNO's office figured it was an odds on bet that if the Soviet Union had the ability to sink this missile-carrying submarine, it would do so—silently and without a trace.

Reasoning behind this Navy viewpoint is based on two hypotheses: One, the POLARIS missile system is the Free World's retaliatory capability that the Kremlin fears the most—even more than Strategic Air Command's long-range supersonic bombers.

Two, the Communist hierarchy's long record of overt aggression and complete prevarication of the facts in the wide-open and above-the-seas world where all can see and hear: Planes shot down over international waters; blatant aggression against small nations like Czechoslovakia, Indo-China, South Korea, Hungary; and the obvious creation of one incident after another for purposes of propaganda and imperialist conquest. Considering this record in the observable, reportable surface and air areas of the world, there is little doubt in Pentagon and White House alike that the only limit to what the Russians will try in the dark and occluded ocean depths is what in fact they are able to do.

Thus, if the GEORGE WASHINGTON had not returned for whatever reason—undersea collision, reactor failure, missile explosion, etc.—the consensus assumption of top Navy officials would have been that it had been sunk by enemy action. And, the whole POLARIS program would have suffered a setback from which it might never have recovered.

But the GEORGE WASHINGTON did return (several times) as have the PATRICK HENRY and the ROBERT E. LEE after her. The fear and apprehension, nevertheless, remain. For though it is pretty certain that the U.S. has a substantial lead on the Soviet Union in undersea warfare and though strenuous efforts are be-

ing made to further improve our status, the chance exists that Red scientists will make the quantum jump here—even as they did in the space race.

And, when they develop the ability to kill this "worst-of-all" menace, they will not hesitate to do so.

This will be the start of "The Invisible War", the war of silence and assumption. The fact that an SS(B)N has been lost may not be known until the vessel fails to show up at the scheduled end of its patrol. Even then the cause will probably not be known. During the nominal 60 days that the POLARIS submarine lurks in its assigned combat patrol area off the great Soviet land mass, it maintains absolute communications silence.

Nor does it appear to have any means of indicating after the fact what type of action might have caused it to be lost.

It is possible that the SS(B)Ns have a means for quick emergency coding of the MAYDAY beacon to indicate the cause of the disaster. Even if this is true (UST, quite properly, could not find out) the chances of the skipper or crew being able to push the right coding button under such circumstances are extremely "iffy". So are the chances that the buoy would be operative after attack with modern underwater weapons.

Commander Frank Andrews, Head of the U.S. Naval Academy's Science Department, writing in the August issue of Naval Institute Proceedings makes the following point:

"One naturally wonders if the pattern of air guerrilla skirmish will ever have a parallel when U.S. POLARIS submarines being operated in the sea areas close to the Russian mainland, or for that matter, when Russian SS(B)Ns begin operating off the coast of the United

States. Either side could use surface or submerged antisubmarine forces against the other. In fact, the submerged ASW forces could launch an attack against the patrolling submarine without warning. If successful, the patrolling submarine would never know what hit him. If unsuccessful, the patrolling submarine may never realize he was under attack."

(Perhaps the most revealing part of Commander Andrews' statement is his switch from the subjunctive to the operative verb form in the last sentence.)

When the first POLARIS submarine fails to return from patrol, the Navy will assume it was lost due to enemy action. This could be weeks after it was destroyed. By then, others could have met a similar fate.

The day this happens Navy submariners in OpNav will cease their heel-and-toe watch of alert vigil and go into action. There will be no declaration of war, no all-out nuclear counterattack on the cities of the Communist world, nor even anything more in the newspapers than:

## POLARIS SUBMARINE LOST ON PATROL CAUSE UNKNOWN

For there will always be that lingering shadow of a doubt that the abort was accidental. And, there will be no way of knowing for certain that it had been a Russian, rather than a North Korean or Chinese submarine, for the attacker will not boast publicly of his prowess. Furthermore, international law of long standing states that a nation threatened by hostile craft hovering within lethal striking distance of its shores may take whatever steps it deems necessary to remove that threat.

Currently, the SS(B)Ns apparently get to the Texas-size patrol areas in complete security—probably by combining high underwater speeds (ballpark, 35 knots) and deep depth with slow silent running and indirect routing. In the invisible war our nuclear attack (sub-killer) submarines will

be brought into play, to act as decoys and, when the opportunity presents itself, kill the would-be killer in silent, deadly undersea warfare.

Where this war actually starts—and there are many in high Naval positions who are convinced that it is only a matter of time—is a point of conjecture, but it will almost certainly be in one of the several POLARIS submarine patrol areas.

Just how it will start relates to submarine operational techniques and comparative U.S. and Soviet capabilities. Current SS(B)Ns have the advantage in both speed and depth. This enables them to reach their patrol areas undetected and untracked. Once there speeds are reduced in general to the minimum required to maintain seaway, one or two or perhaps half a knot. This is the nuclear sub's quietest operational mode—except when it is running on batteries which it can only do for very limited periods. On nuclear power at any given speed the A-sub makes more noise than a conventional sub at the same speed—all other factors being equal. Thus, assuming equal passive sonar capabilities a stalking conventional sub could, theoretically, detect a lurking A-sub sooner (in terms of range) than vice-versa. Active sonar will not be used except under very unusual circumstances in sub-to-sub warfare, since the "ping" will alert the hunted long before the hunter knows he has a target.

In a word, for Russia to sink our SS(B)Ns with relative immunity she must develop the submarines, sonar, and the weapons capability of accomplishing this. For us to retain our immunity we must maintain operational superiority. Thus, on the level of technology the battle here, as elsewhere, is already joined.

Once this invisible war starts, it will spread beyond the limits of merely sinking and/or protecting SS(B)Ns. For one thing, sonar and other detection/identification devices are not good enough yet to separate missile-carrying subs from other varieties. This will mean that almost immediately it will be open season on any Red U-boats hovering off New London, Charleston, S.C., Key West, Cape Canaveral, Holy Loch, etc., etc. Red U-boats will, of course, counter in kind, and it will be a hot war in the cold depths. Perhaps the only hints we'll see on the surface will be an upswing in notices to the next-of-kin of non-returning submariners, and a sharp increase in the procurement of tactical undersea weapons.\*

## SUBMARINE OF 1970 POSES R & D PROBLEMS

THE SUBMARINE AS A WEAPON is today capable of the strategic bombardment of land-mass targets, hunting and killing other submarines, attacking surface ships, laying mines, carrying out a variety of reconnaissance, landing and recovering specialized amphibious forces such as underwater demolition teams and special operatives, rescue, and other specialized support activities. The basic mission of the submarine is ASW. This is even true of POLARIS subs—after they have fired their missiles.

It has an operational depth capability of rather less than 1,500 feet and a maximum underwater speed on the order of 35 knots. The nuclear submarines can remain submerged indefinitely (limited only by their atomic fuel supply, which appears to be good for a couple of years of continuous cruising). Human factors, however, limit practical patrol times to little more than 60 days continuously submerged.

The modern fleet submarine is much quieter than its predecessors, but is still far from silent. It has a useful acoustic detection range of from 30 to 100 miles, depending on sea conditions, nature of the target, etc. The range of its weapons falls considerably short of this mark, and will continue to do so even after the addition of SUBROC to its armament.

The future of the submarine as a weapon is deeper, faster, quieter, and a greater variety of armament. Continuous discussions are currently underway at the Pentagon on what the submarine of the 1970's will look like; what will be its capabilities and missions.

In current thinking the philosophy of the one big boat that can do everything continues to prevail over that of those submariners who feel that submarines should be designed and constructed for specific missions. The latter, however, may see some of their ideas put to practice before the decade is out—in the form of small fuel-cell (or other) powered interceptor craft capable of high sustained speeds and extended submergence.

But the backbone of the Navy's underwater fleet of tomorrow will be big boats with a wide variety of offensive capabilities.

However, the Navy hopes to see developed a whole family of weapon. All of which will fire through

torpedo tubes—which, Navy anticipates, will be enlarged somewhat from their present 21-inch diameter. Missions of this weapons family will cover tactical (and local strategic) land bombardment (up to 1,500 miles range), amphibious support, sub-to-sub, sub-to-surface ship, sub-to-aircraft, and, of course, mine laying.

The next quantum jump in extending present operation depth capabilities will be to 4,000-to-6,000 feet. This contrasts with 200-to-400 feet in World War II, and will probably require new concepts in materials, structures, and basic submarine design (See The Pressure Barrier, May/June UST, p. 38).

Speed requirements, if the submarine is to maintain its present proportional advantage over the surface craft that hunt it, will be severe. In prospect are hydrofoils and Ground Effect Machines with surface search speeds on the order of 100 knots. Ideally, the submarine should be faster than that, though this seems unlikely without revolutionary design changes in propulsion and hydrodynamic shape and techniques. This capability, however, will be intensively sought.

As any submariner knows, the undersea craft does not exactly boast an excess of space. Thus, the family of weapons that is developed should consist of a number of basic interchangeable components which can be assembled together in various combinations in order to achieve any given goal: Such things as common boosters, common guidance packages, etc. In a word, a true multi-purpose missile is sought.

Sub-Arctic warfare is one of the more interesting developments of the future, and one which promises to develop into quite a substantial research and development market.

Needless to remark, as submarine speeds go up and depths go down, comparable advances will have to be made in sub-to-sub weapons—whose minimum speeds should be at least one-third greater than their targets. This means advances in torpedo propulsion, development of the capability for torpedoes to listen effectively at these speeds. There will have to be intensive development of evasion devices, decoys, chemical noise-makers, and all of the things required to achieve a versatile, completely self-sufficient underwater weapons system.\*

# THE OCEAN

*Roll on, thou deep and dark blue ocean—roll, ten thousand fleets sweep over thee in vain; man marks the earth with ruin—his control stops with the shore — Byron*

By Robert M. Snyder

Woods Hole Oceanographic Institution

Man has been pretty well able to shape the solid earth to conform to his needs and desires. The land has yielded to brute force and persistence. The ocean commands a bit more respect. But, respect is not enough. Man cannot ignore the sea. The Pacific ocean alone blankets more of our planet than all of all the land together (32.4 percent compared to 29.2 percent). The sea is indifferent to the noblest of man's efforts and if we are to ply it in safety and with success we must gain a realistic knowledge of the forces it commands.

The first deep-sea oceanographic cruise was that of the HMS CHALLENGER which sailed around the world (1872-76) taking water and bottom samples. Her bottom samples laid the foundation for geological oceanography and her water samples showed for the first time that, relatively speaking, the waters of the world were chemically homogeneous.

The origin of the oceans is still an uncertainty. It is pretty well agreed among geologists that the crustal rock underlying the oceans is fundamentally different from that which makes up the continents. The lighter (silicic) continents are likened to great icebergs "floating" on the earth's mantle, their basements pushing deeply into the earth to support their protruding mass. Continuing this analogy the heavier basic rocks beneath the oceans would be similar to great thin sheets of ice displacing only slightly the mantle on which they rest. And again, protruding only slightly upwards they form great natural basins for the collection of terrestrial water.

There is not such good agreement on the origin of the ocean water. Some geologists feel that the earth, upon cooling, received torrents of rain condensed from the primordial atmosphere. Others feel that the atmospheric vapor was lost to space and that the ocean waters gradually accumulated from volcanic steam and hot springs. In any event about 85 percent, or 328 million cubic miles of the earth's crustal water is now in the oceans. The mean depth of the sea is 12,450 feet and 65% of the

sea or 46 per cent of the surface of the earth lies below 2 miles of water.

Approximate areas of the seven oceans in millions of square miles are as follows: Arctic 5.4, mean depth 3,950 feet; North Atlantic 18.1, mean depth 10,780; South Atlantic 14.4, mean depth 13,420; North Pacific 31.5, mean depth 14,050; South Pacific 32.2, mean depth 12,660; Indian 25.3, mean depth 12,770 and the Antarctic 12.5 million square miles with a mean depth of 12,240 feet.

**Near shore features:** At present the ocean contains more than enough water to fill its basins, and it encroaches upon the continents themselves. Seven percent of the area of the ocean lies upon the continental shelves—a seaward extension of the coastal plains. These continental shelves have a characteristic slope of 10 feet per mile and extend an average of 42 miles seaward. Their extent is not everywhere uniform, however, varying from one mile off the west coasts of Chile and California to more than 750 miles beyond the northern borders of Europe and Siberia.

Beyond the continental shelf at a depth conventionally taken as 600 feet, but which actually varies from 160 to 3000 feet, the slope of the ocean floor increases rapidly. This region of maximum grade is known as the continental slope. The continental slopes claim another 17 percent of the earth's surface.

Both the continental shelves and the continental slopes are areas of oceanographic interest. Most of the world's great fishing banks are on the continental shelves, and since they are actually part of the continents they are being explored for possible mineral deposits.

The continental slopes from the lateral boundary of the oceans and because of their grade are susceptible

to erosional processes. Great submarine canyons are associated with many of the world's major rivers. Although the heads of these canyons were undoubtedly cut by the rivers during the Pleistocene Age when the great ice sheets lowered sea level by several hundred feet, the outer reaches of the canyons involve depths too great to be explained by ordinary stream cutting. Turbidity currents, comparable to terrestrial avalanches, may be the prime agent in this deep sea erosion.

Other near shore features include the continental islands, e.g., the Bahamas, which are merely high points on the continental shelves.

The topography of the near shore areas has been studied most extensively, not only because of its importance to navigators, but because the bottom configuration greatly effects the circulation of water, beach erosion, fish migrations and feeding grounds, terrigenous (from the continents) deposits which plug our harbors and inlets and, in many parts of the world, the climate itself.

**The Deep Sea:** Beyond the continental slopes, below more than 10,000 feet of water, lies more than half our planet's surface. The features that mar the abyssal plains are more diverse and of greater magnitude than those that complicate the land.

Nearly all oceanic islands are volcanic in origin. Many of these oceanic peaks do not reach the surface and are known to the oceanographer as Sea Mounts. These islands and peaks are more permanent than similar fixtures upon the land because the common forces of erosion are lacking in the sea. During the past the peaks of many of these islands were eroded by wave action and have subsequently subsided well below present sea level. These truncated sunken islands are known as guyots and the tops of some are as deep as 6,600 feet. Where water temperature and other conditions were right coral reefs formed atop the receding sea mounts and guyots and today form

the familiar coral atolls of the Pacific.

Another gross feature of the sea floor is the oceanic trenches. These are characteristically elongated V-shaped grooves and are generally paralleled by arcs of active volcanoes which, in most cases, rise above the surface to form island arcs. Table I lists the seven deepest known trenches. In addition to these trenches there are others not associated with active volcanoes. Among these are the Romanche Trench and the South Sandwich Trench in the Atlantic and the Byrd Deep in the South Pacific.

Another striking feature of submarine topology is the mid Atlantic Ridge—an enormous mountain range that divides the Atlantic into 2 basins. The Ridge extends from Iceland to Bouvet Island.

**The Oceanic Environment:** The major parameters of the oceanic environment of interest to the oceanographer may be divided into four groups: Geological, Physical, Chemical and Biological. Bottom topography greatly effects certain parameters in each of the four disciplines. Types of sediment and rates of sedimentation depend upon geographical location, bottom contours and deep ocean currents. Deep ocean currents are effected in turn by chemical composition (salinity), temperature and density gradients and bottom topology. Biological distributions can be explained in terms of ocean currents (upwellings) which distribute nutrients from the deep waters and these biological organisms directly effect the chemistry (oxygen content) of sea water.

**The remaining boundary** of the ocean, not yet mentioned, is that which meets the earth's atmosphere. The study of this interface is a science in itself requiring a knowledge

of meteorology as well as physical and chemical oceanography. Solar heating takes place from the surface to depths as great as 30 feet—the limit of penetration of infra-red radiation in sea water. This heating causes gradients up to one-half degree F per foot. Cooling by evaporation takes place in the first 0.05 inch or less and may cause an inverse gradient of 1° F per 0.05 inch.

The action of the wind upon the sea mixes the surface waters to uniform temperature to depth of 600 feet and hence warms the sea well beyond the reach of the sun. The driving force of the wind is responsible, in part, for many of the great surface current systems of the oceans. Waters heated by the tropic sun are carried toward the poles where their heat is given off to the atmosphere greatly effecting the climates of the lands to leeward.

**Research in The Oceans:** With the great amount of interdependence of the various realms of scientific investigation in the sea it is difficult for the oceanographer to know where to start. Obviously he must be a sailor or at least be able to communicate with those who sail professionally.

Theoretical investigations in oceanography got underway at about the same time as the early expeditions, i.e., the late 19th Century. The theoretical approach proved most useful in predicting the various types of ocean currents based on the relationship between chlorinity, density and salinity and upon wind driven waves, Coriolis forces and eddy viscosity. There are so many factors effecting currents that, without the theoretical background to serve as a basis for measurement, the observed data would be impossible to interpret. The usefulness of the theoretical approach is in the end, however, limited by its substan-

tiability. Men must go to sea if they are to appreciate the meaning of their equations.

Every aspect of the sea has been found, in recent years, to be vastly more complex than was thought to be the case 40 or 50 years ago. The deep sea floor, for example, was thought to be a great level plain dotted here and there with volcanic islands. Prior to 1920 all soundings were taken with the lead line. Even in its later stages of development (a 0.090" steel piano wire attached to a high speed winch) the lead line was inefficient and a great deal of time was consumed in taking one sounding.

**There still remain vast areas** in the oceans that have not been studied with the echo sounder. Precise bottom detail charts are needed to aid in the navigation of ships and submarines and detection and/or evasion of submarines can be facilitated by a study of the thermal structure of the upper oceans. But temperature studies and echo sounding have been routine for some time and these problems can be attacked directly without further instrument development. Certainly the refinement of equipments and techniques may be found necessary but the state of the art is advanced enough to permit direct applications.

There are areas of oceanic study, however, where our knowledge is fragmentary at best. Studies of the interaction at the sea-air boundary, for example, are extremely difficult because the presence of a ship or the measuring instrument itself can be disturbing enough to make the data meaningless. Obviously problems such as this must be attacked indirectly until improved measuring techniques are developed. In certain areas, then, our knowledge is so limited that the oceanographer cannot intelligently decide in which di-

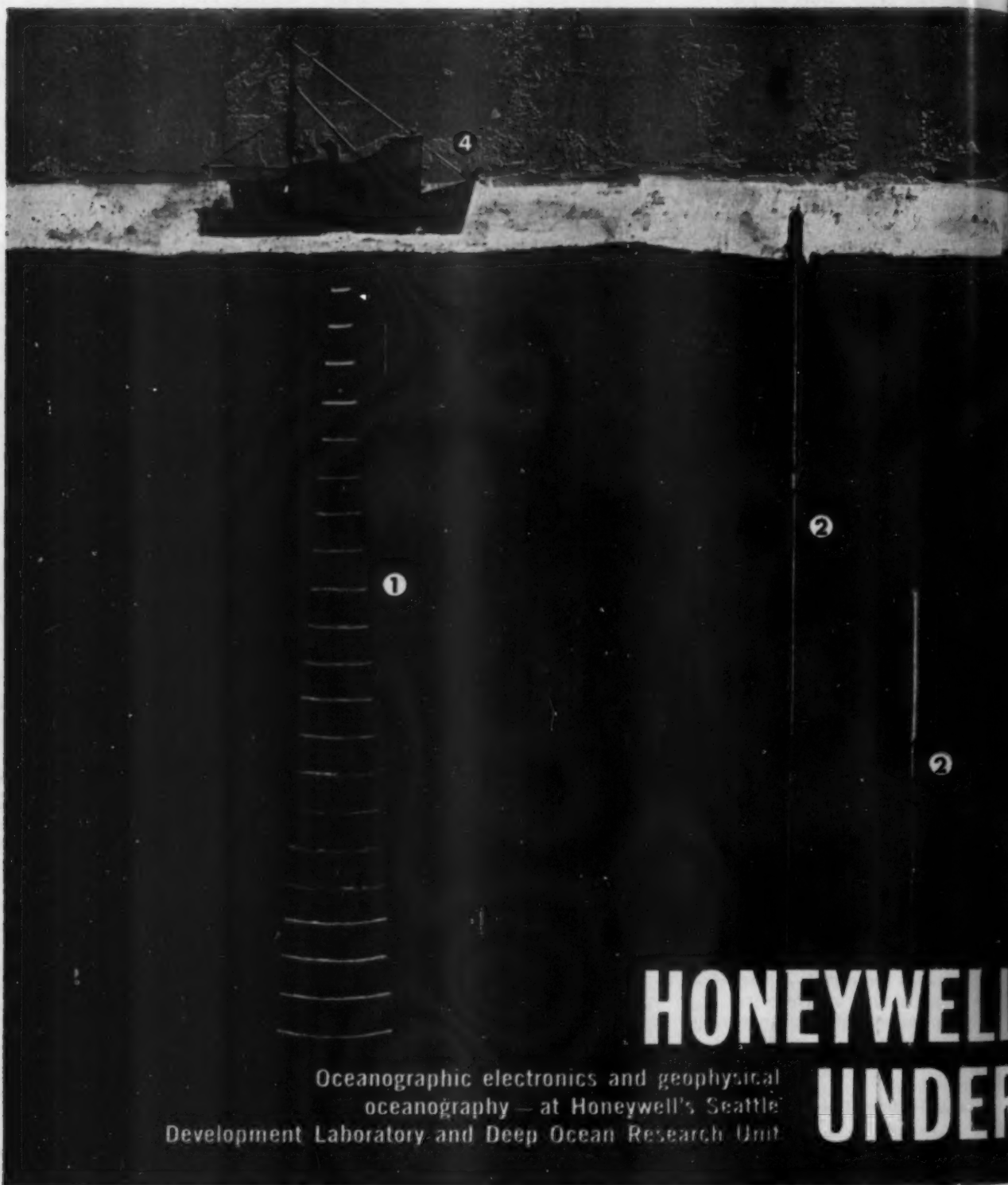
**Table I—Deep Ocean Trenches**

Name	Depth
Kuril-Kamchatka Trench	34,077 feet
Japan Trench	34,038 feet
Mindanao Trench	34,440 feet
Marianas Trench	35,958 feet
Kermadec Trench	35,445 feet
Tonga Trench	35,341 feet
Brownson Deep*	27,498 feet

\*The Brownson Deep lies north of Puerto Rico. All other deeps listed are in the Pacific.

**Table II—Oceanographic Parameters**

	Range in the Open Ocean	Instrument for Measuring or Collection	Depths	Factors
Temperature (T)	-2° C to +30° C	Bathythermograph Reversing Thermometer	0-900 ft typical 0-35,000 feet	
Salinity (S)	33°/00 to 37°/00	Nansen Bottle	0-35,000 feet	T, D, S, C
Pressure (P)	0 psig to 16,000 psig			
Sound Velocity	4400-4900 ft/sec	Bureau of Standards Velocimeter	0-35,000 feet	
Electrical Conductivity (C)	0.01 to 0.06 reciprocal ohms/cm <sup>3</sup>			S, T
Ocean Currents	0.00 to 7 knots	Drogues Sonic floats Roberts meters Richardson meters		
Waves	0 to 60+ feet in height less than 1 to over 20 second periods			Wind velocity Fetch



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# LI ER THE SEA

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rection he should go. In this instance he should be allowed to proceed on the basis of his experience and intuition. Research on this basis can be extremely rewarding although the rewards may come in a way quite different from the researcher's original intention.

**The Ocean as a Laboratory:** Table II lists some of the parameters of the oceans which lend themselves to direct study. Certain instruments used universally in making these studies have been listed. Those in use up to 1942 are described in reference (1), and reference (2) serves to update this listing to 1952.

Instruments used on the continental shelves rarely have to be lowered below 1000 feet where the pressure is only 445 pounds per square inch. Certain measurements made in the open ocean are restricted to this range of depths, e.g., plankton nets, devices to measure the penetration of sunlight, buoyed wave meters,

meters for measuring wind driven currents, and instruments used for measuring the acoustical properties of the deep scattering layer. Obviously some instruments may be left open to pressure, but others must be enclosed in housings that will protect delicate electronic components from the corrosive action of the salts. To do this they must withstand the pressures exerted by the sea.

Much of the sea (over 75%) lies between 1000 and 20,000 feet where the pressure varies from about 450 psi to over 9,000 psi. Most oceanographic work which takes place within this volume of the sea is that of the chemical and physical oceanographer. Water samples are taken to determine the exact composition of the water. Salinity, temperature and sound velocity measurements consume a great deal of ship time in water of these depths. Within the past few months the

current measurements made in this area vastly outnumber all of those made previously and yet we still know less about the first 20,000 feet of ocean than we do about the first 36,000,000 feet of space.

The rest of the sea, which lies between 20,000 feet and 35,958 feet where the pressure is 16,415 psi, claims only a small part of the earth's surface. These are the deep ocean trenches and are the object of special study.

**The oceanographer's tools** may be divided into two groups according to their mode of operation: (1) Those that collect samples to be analyzed aboard ship or at a shore-side laboratory and (2) those that make *in situ* measurements where the data is either stored or telemetered to the ship or shore station.

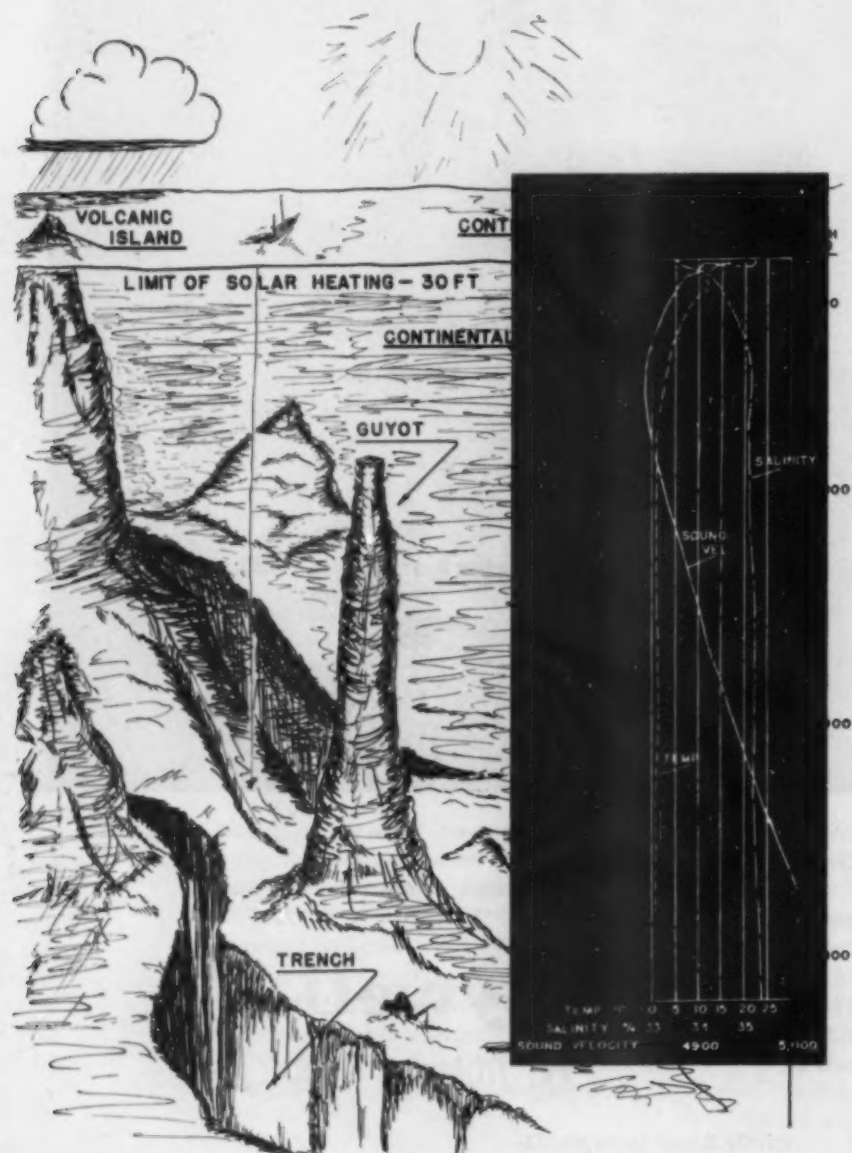
The first group includes bottom corers, dredges, water sampling bottles, plankton nets, etc. These devices obviously do not require transducers of any sort but must be carefully engineered to be self aligning and are generally actuated by contact with the bottom or by other mechanical means.

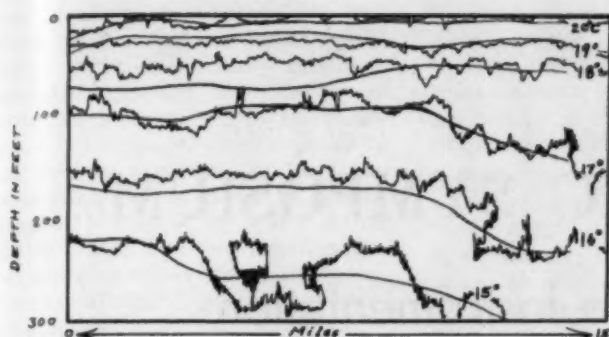
The instruments that make *in situ* measurements are diverse in type and degree of complexity, ranging from the simple reversing thermometer to the complex STD (Salinity-Temperature-Depth Recorder).

**The development of instruments** along conventional lines is not always possible in the field of oceanography. This is true for many reasons. Firstly, controlled experiments at sea are next to impossible. Instruments for measuring temperature for instance must have provisions for automatically correcting for pressure effects or must record the pressures so that correction can be applied. Secondly, power requirements must be kept low because the power source must either be carried within the instrument or cabled to it from the ship.

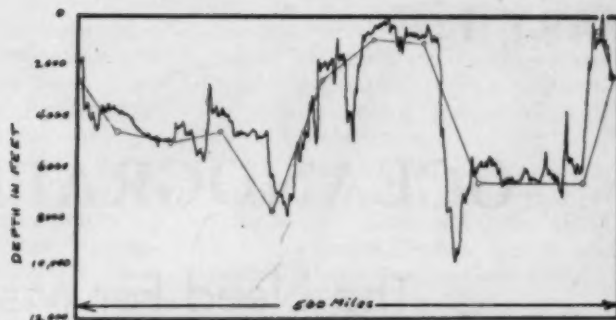
Research must be carried out from a practically uncontrollable platform in a corrosive atmosphere at reduced physical and mental efficiency and the instruments must withstand pressures of tons to the square inch in one of the most corrosive natural liquids known to man, must withstand repeated banging against the hull of the ship, shock loads which would frighten the operator of a wrecking crane and still must be able to measure concentrations to one part in 4000, temperatures to 0.01° C and/or water motion as low as 0.01 kt with a high degree of reliability.

The need for rugged, unsophisti-





Here, in color, is a hypothetical bottom profile taken by lead line; black trace is that of precision depth recorder, which shows far greater precision.



Here, in color, is a typical temperature profile based on numerous bathythermograph lowerings. Black trace is from continuous electronic temperature profiler.

cated instruments cannot be over-emphasized and there is no substitute for working at sea to acquire an understanding of the problem.

In some cases where samples of water, bottom sediment or plankton are collected, the oceanographer cannot wait until he returns to the comfort and safety of a laboratory on the beach to analyze his findings; for the information he collects on the first day may well determine the proper course for the second day.

In some cases there are a great many steps necessary between the output of an instrument and a sensible presentation of the data. Unless programs are well thought out in advance with due consideration to all possible factors the researcher may find to his annoyance that his hard earned data is wholly inadequate.

Costs of running a ship range from a few hundred to over \$6,000 per day. Because of this, work must go on around the clock and cruises must be planned so that efficient use is made of every hour regardless of equipment failure or inclement weather. This is a big order and quite impossible to fill without access to instruments that are basically reliable. Even on the most economical of deep sea cruises using the most reliable equipment, temperature information comes as high as \$7 per digit and sea water samples at more than \$11 a fifth.

It should be obvious from the above why oceanographers are loathe to accept new and unproven equipment.

Designing a piece of gear in an air conditioned office and getting it to function on a laboratory bench will hold little reward for the sea going scientist. Only after the gear has been banged about the ship, doused with salt water and been subjected to extreme pressures, all the while reacting only to its designed stimulus, can the oceanographer rejoice.

**The Oceanographer as an Engineer:** The oceanographer isn't completely alone with these problems. The meteorologist must also extend his senses, through the use of instruments, miles beyond his laboratory. The men who log oil wells must fashion instruments to withstand higher pressures, higher salinities and temperatures far more extreme than those found in the ocean.

The meteorologist's requirements for accuracy, however, are not as strict as those of the oceanographer and the oil well logger's instruments are confined to a definable hole in the ground.

One of the simpler unsolved problems in oceanography today is a fast, reliable, accurate method for determining the instantaneous depth of a lowered instrument. The amount of wire payed out from a winch is a poor indication of depth because of the effect of ship drift and ocean currents. The speed of sound in sea water is not sufficient to yield the desired acquisition rates and pressure transducers which are sensitive over a range from 10 to 10,000 psi are not easy to find. And any large power consuming devices would impede the instrument in question.

**Help From Industry:** Oceanographers still do not have a great deal of money to spend. Until recently little emphasis has been placed on ship design. Oceanographic ships have typically been converted from patrol craft, fishing boats, warships, yachts and cable layers. With new ships being designed and built specifically for research there are bound to be new approaches to instrumentation. Computers have become standard tools of the oceanographer when he can acquire enough data to warrant setting up a program.

Electronics plays a major part in oceanography today and solid state devices are finding more and more application.

In the past most successful instruments have been designed and built

by the researcher who used them. It is extremely difficult to design and build gear for someone else to use at sea and a researcher who is not interested in the details of the instrument he employs cannot possibly use it with maximum efficiency. If a great deal is required of the instrument itself then a great deal more is required of its user.

An engineer can design and build for a customer an automatic machine to build components and the operator can use it successfully without understanding either how it operates or what it does. This is definitely not the case in oceanographic research.

To the oceanographer, using an instrument means (1) loading it with batteries, film, recording paper etc., (2) assembling it making sure there are no shorted or stressed wires and that the pressure seals are clean and engage properly, (3) getting it on deck and properly secured to the lowering cable, (4) getting it over the side, clear of the screws and lowered to the required depth and (5) retrieving it safely to the shipboard laboratory, (6) recovering the record, and (7) trying to determine why it didn't work. This is quite different from placing an instrument on a laboratory bench and plugging it into a wall socket.

In short then, if the industrial engineer would like to be of help to the research oceanographer he must first find out what the oceanographer's abilities are at present, second what the oceanographer would like to be able to do and third whether or not he can save the oceanographer time, trouble and money by taking on some of his problems.

There are all too many industrial organizations today that would like nothing better than to take on an open end contract to solve all the problems of the deep sea scientist. There is a sad lack, however, on the part of these people of a willingness to gamble on their ability. ★

## PART I

# OCEANOGRAPHIC SYMPOSIUM

## The Need For Marine Instrumentation

*Part II of this report will appear in the Nov./Dec. issue of UST and will present a breakdown of the type instrumentation needed by various agencies.*

by

Richard E. Munske

IN THE PAST, the government has always been rather reticent about any technical atony. Admission of a weakness or scientific ignorance seems to be a humility few people are willing to accept. This was not the case at the recent Government-Industry Symposium on Oceanographic Instrumentation. This was an all out effort, on the part of the government, to familiarize industry with (1) the present state-of-the-art, (2) the value of future oceanographic research, and (3) the critical need for modern instrumentation.

In early 1959 the National Academy of Sciences published their report, "Oceanography 1960-1970" which revealed the altogether inadequate progress that had been made in the marine sciences in this country. This led to the formation of the Interagency Committee on Oceanography (ICO)—the prime purpose of which was to coordinate the activities of all government agencies engaged in marine studies, and channel them into a meaningful program. The committee is now composed of representatives from the Atomic Energy Commission, the National Science Foundation, and the departments of Health, Education and Welfare, Defense, Interior, Commerce, and Treasury.

One of the first steps the ICO made toward the development of its program was the establishment of the National Oceanographic Data Center (NODC), under management of the Naval Hydrographic Office. NODC processes various kinds of oceanic data and makes it available to the government, industry and private institutions for scientific research.

*This report is intended not to review the design and performance criteria of the needed instrumentation, but to point out that a grave situation does exist due of the lack of adequate instrumentation. The problem has become near-critical, and the security and welfare of this country could depend largely on the progress that must be made in the marine sciences.*

But even the tremendous amounts of data that pass through the NODC could be useless without proper scientific methods, mathematical formulae, or highly advanced instrumentation that can handle such large quantities of information. Some time ago, the center was approached by three individuals who requested computing and tabulation assistance on a research project. Data from a large number of weather stations were to be collated and appear on separate sheets. It was soon pointed out that if the three persons were to read the tab sheets at the rate of one line a minute, 24 hours a day, they wouldn't live long enough to finish reading, let alone analyzing.

It wasn't long before the ICO saw the need for an instrumentation re-evaluation and overhaul. Hence, the symposium.

Getting down to hard facts, just what are the oceanographic needs? Typical of the requirements of the various agencies are those of the Coast and Geodetic Survey.

Since they are concerned with the preparation of maps and charts, they need data to plot the ocean floor. Their surveys include measurement of gravitational and mag-

netic fields, distribution of temperature, density, currents, and classification of sediments.

Instrumentation may be ship-board or in the form of buoys to provide synoptic data on currents, waves, etc. Most important for ocean bottom surveys are an accurate and reliable navigational positioning system and a rugged but precise depth sounder. Progress is being made with the narrow beam oscillator to provide vertical depth measurements, but still requires perfection. Lack of effective stabilization techniques prevent much survey work to be conducted in "bad weather". When a 3000-ton ship can cost as much as \$3000 a day, the rough seas can be mighty expensive. This can be offset with improved equipment that will permit obtaining more data in less time with greater accuracy.

The necessity of equipment sophistication can be illustrated by a point made by Mr. James Snodgrass of Scripps Institute. Back in the late 1700's Ben Franklin prepared a map of the Gulf Stream by taking temperature readings of the water with a thermometer and a wooden bucket. This led to his concept of thermo-metrical navigation. Today, nearly 200 years later, this same technique is being used, except the wooden bucket has been replaced by a "metal" one—which, by the way, is not quite as accurate as the former. So much for the "dark ages" techniques.

It must be realized that 80 per cent of the oceans pass the 3000 meter mark, and out of this figure 27 per cent go beyond 5000 meters. This means pressures in excess of 7000 psi. Instruments can cope with these pressures in three ways. They

can be enclosed in rigid pressure-proof capsules, taking advantage of both geometric and materials strength; they can be made out of materials inherently capable of satisfactory operation when exposed to the ambient pressures; or the components can be encased in a potting compound (liquid or solid) inside its container. The two latter methods, considered as being in "pressure equilibrium", seem more feasible due to cost and weight savings.

The effect of hydrostatic pressures on solid state components varies greatly. Resistors, for example, undergo a significant change unless metallized or wire-wound types are employed, although there is still some effect on these. There is no problem with non-electrolytic capacitors, but the electrolytic variety experience peculiar changes. As pressure increases, so will leakage. Oddly enough though, capacitance shows an improvement at 8000 psi and up, reaching an optimum peak around 20,000 psi. In some instances, when the capacitor is returned to ambient pressure, it proves to be a better unit. Subminiature electron tubes can take a considerable amount of pressure, as can relays and microswitches. But stepping switches require appreciable lubricity. Clocks usually function satisfactorily providing fluid viscosity is low enough. Many types of transistors cannot withstand high pressures, collapsing around 10,000 psi. Most types can be potted in a plastic resin, enabling pressure equilibrium. (0.125 in. wall thickness of plastic material is usually sufficient for small transistors.) Several manufacturers are producing semiconductors with passivated surfaces, so they can be potted without fear of contamination. Flashlight bulbs, used in luminescence measurements, can take as much as 20,000 psi with no ill effects. Batteries need improvement. Silvercel are the only type known to operate as desired under 80,000 psi.

The field of plastics needs more attention. Polyethylene, Teflon, and epoxies are about the only plastics that are acceptable. One thing pointed out at the symposium was that synthetic salt spray tests used in environmental testing have not proven to be effective. This may be the cause of unsatisfactory plastics, since the tests do not simulate true salinity conditions.

The Naval Hydrographic Office has prepared an extensive list of instrumentation and systems re-

quirements—along with performance criteria—for the three types of ships that will be concerned with marine studies. These three types are: Ships of Opportunity, Synoptic Ships, and Survey Ships.

Synoptic Ships will employ an instrument system designed for the express purpose of rapid collecting and reporting by radio communications of key oceanographic data. These ships will be ocean station vessels, radar picket ships, and selected combat Fleet units. They constitute part of a regional observation network, and will operate at a "lying-to" or slow speed (0-5 knots) status.

Ships of Opportunity are those whose primary mission is other than research, such as aircraft carriers, destroyers, mine sweepers, cargo ships, ice breakers, etc. Their "instrumentation suit" is designed to be utilized by ships "underway", at speeds of 0 to 18 knots.

The Survey Ships have the most exacting and critical requirements, since they are specifically oceanographic survey vessels. Their needs cover marine biology, sonar, navigation, telemetry (a big problem due to lack of frequency allocation), geophysics, magnetics, etc.

All three ship types require essentially the same kind of instrumentation, but with varying degrees of accuracy. The quality demanded in each case is far above that of existing equipment. Reliability, ruggedness and long life are emphasized and re-emphasized.

Because of the numerous ships that are to be equipped with the "instrumentation suits", another critical factor must be considered—maintenance. Equipment must be sophisticated enough to perform reliably at the quantitative and qualitative levels desired, yet be simple enough to undergo at-sea, in-operation maintenance in the event of breakdown.

Much of the data collected will be used for ASW (antisubmarine warfare) and ASWEPS (antisubmarine weapons environmental prediction systems) applications. Considering the immensity of the oceans, there are very few temperature and depth readings available for analysis and utilization. Since ASWEPS is concerned with determining optimum sea lanes for Naval movements, this data is mandatory and deserves immediate attention. ASWEPS is looking for aircraft-carried infrared scanners for measuring temperatures and determining ice conditions. Air-dropped systems

for applied research instrumentation are needed. Special equipment looked for are wave height meters, bottom reflectivity meters (currently not available) and solid state current detectors.

The Naval Bureau of Ships wants instrument protection from that old salty dog—"corrosion". They would also like sound velocity meters and higher precision slope-recorders.

The Bureau of Weapons is concerned more with surveillance systems such as radar, sonar, magneto-electric (an improved version of MAD—Magnetic Anomaly Detection) and Sonobuoy (explosive echo ranging). Where equipment exists, it needs improvements; where it doesn't exist, it should.

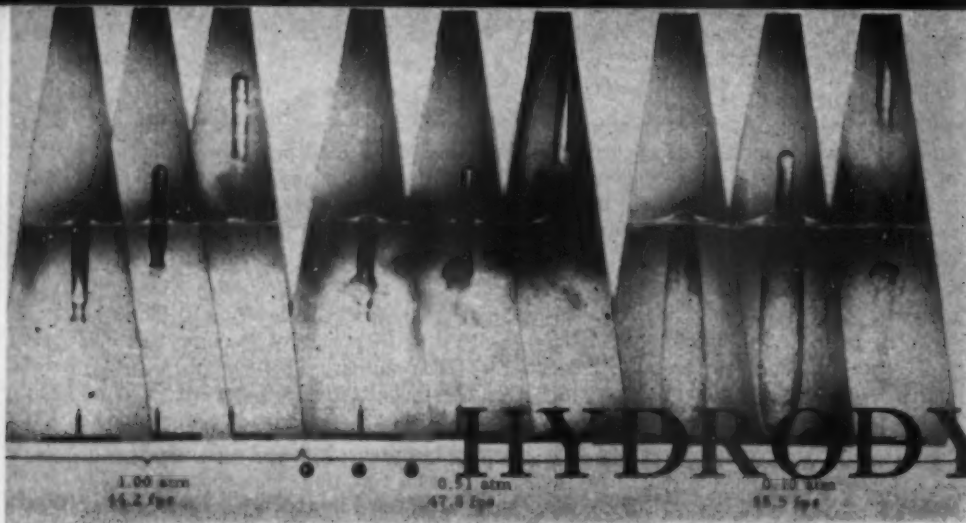
Present day sensors, used in the gathering of much undersea data, are either analog, digital or of the variable-frequency type—all of which have a limited output range, thereby affecting accuracy. Although the modular concept of stacking sensors to collect data simultaneously won't improve accuracy, it will result in economies. Since sensors are probably the most numerous measuring devices, some link should be made between them and recorders and/or telemetry units.

Progress in the field of buoys has not been extensive nor remarkable, according to Dr. Richardson, of Woods Hole Institute. Data from buoys are short-term measurements and must be handled rapidly. This could be accomplished with telemetry systems, that are presently non-existent, in the buoys.

Design of instrumentation, heretofore, has been mainly intuitive, and engineering efforts have been naive, or in some cases, primitive. The consensus of the Symposium was: Something must be done . . . and fast!

The Symposium was a step in the right direction, but it can't stop there. So much time can be spent talking—now there must be some doing. Research institutes encourage engineers (particularly the design variety) to partake in marine exploration and surveys in order to better understand the problems and inadequacies of oceanographic instrumentation. There is no understanding like doing.

Why is it, that in so short time, we have reached so far out in space, when we have hardly "wetted our toes" in that which is so close to us . . . the sea?



missile  
water  
exit...

# HYDRODYNAMICS

**WATER-EXIT BEHAVIOR OF MISSILES** has recently assumed great importance. But at present little is known about this subject. Available water-exit behavior data indicate that missile water-exit perturbations may take place under conditions of fully wetted flow and under conditions of cavitation. However, very little data are available on missile-water-exit perturbations under varying degrees of cavitation such as might arise in practical application. In addition, no data appear to be available for assessing the validity of modeling parameters in modeling missile water-exit behavior under conditions of cavitation.

These preliminary missile water-exit studies constitute the exploratory phase of a two-purpose program: (a) to determine if missile water-exit perturbations under conditions of cavitation are sufficiently large to pose problems in missile water-exit technology and (b) to provide data for a subsequent program to assess the validity of modeling parameters in model-

*This article by Dr. J. G. Waugh, H. R. Kelley, and A. G. Fabula, Naval Ordnance Test Station, Pasadena Annex, Calif., is the first of a series which will appear in UNDERSEA TECHNOLOGY based upon the proceedings of The Fifth Navy Science Symposium sponsored by the Office of Naval Research at the U.S. Naval Academy at Annapolis, Md. earlier this year. Those in future issues will cover hydrofoils, hull damping, transducers, etc.*

ing missile water-exit behavior under conditions of cavitation.

The missile was launched under fresh water in the Variable-Angle Variable-Pressure Launching Tank in the Hydroballistics Laboratory, NOTS, Pasadena. In this tank, missiles up to 2 inches in diameter can be launched under water with a maximum velocity of about 90 fps. The launching angle can be varied from 5 to 90 degrees with respect to the horizontal, and the

gas pressure over the water surface can be varied from 1.5 to less than 0.1 atmosphere absolute.

The initial launching velocity was adjusted to give a nominal missile velocity of 60 fps just before water exit.

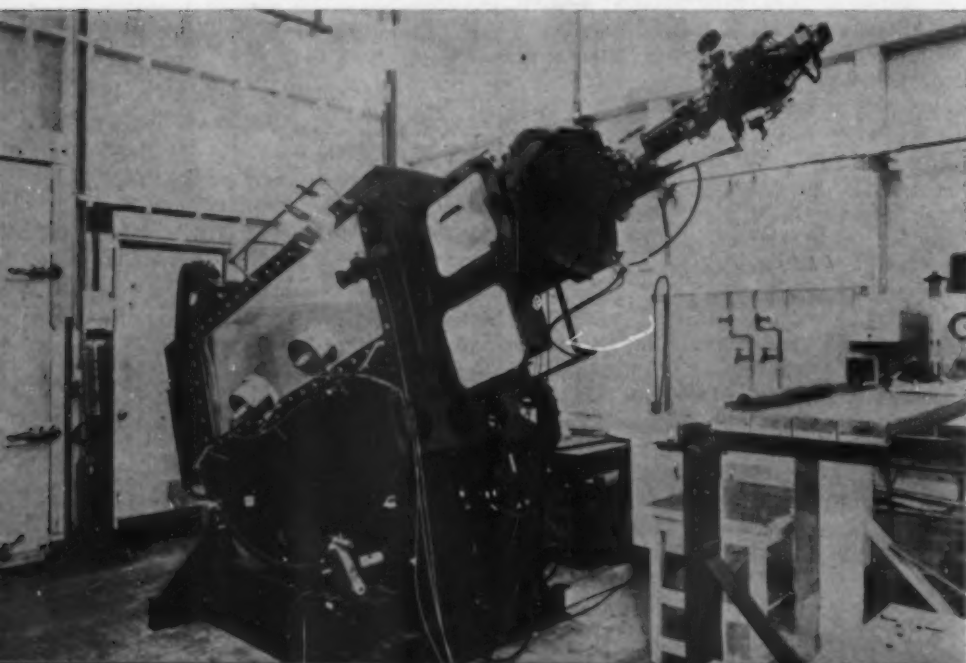
The action of the launcher does not introduce any air, gas, or other extraneous substances into the water and the water is deaerated by bubbling air through it at 0.1 atmosphere (the lowest pressure used in these studies) for at least one hour before use—thus assuring pure water-vapor or very nearly pure water-vapor cavitation. The degree of missile cavitation during its underwater trajectory and at water exit is adjusted by varying the air pressure over the water surface, i.e., varying the cavitation number. Air pressure in these tests ranged from 0.1 to 1.0 atmosphere absolute.

Side-view water-exit data were obtained with a rotating-disk camera and Edgerton-type stroboscopic flash lamps adjusted to give nineteen exposures at a frequency of 250 per second, i.e., a time interval of 4 milliseconds between frames.

**Test conditions** required certain assumptions and compromises. The largest missile the launching tank can handle is about two inches in diameter. Furthermore, in order to be able to scale up model test results, it is necessary to assume, a priori, that one-to-one Froude and cavitation-number scaling will be valid for modeling service missile behavior if Reynolds number and gas-density effects can be ignored. This assumption seems reasonable but will be investigated in a later program.

In order that the effects of non-modeling of the Reynolds number be minimized without artificial turbulence stimulation, velocities must be sufficiently high that the Reynolds number for both model

Variable angle, variable pressure launch tank.



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and prototype will correspond to transition from laminar to turbulent flow close to the nose. For prototype (service) missiles this restriction would offer no problem, but for a 2-inch-diameter hemisphere-head missile, the critical Reynolds number probably corresponds to a missile velocity somewhat below 60 fps. Therefore the velocity of the missile should not be less than 60 fps. On the basis of Froude scaling, 60 fps water-exit velocity would correspond to 190 fps for a 20-inch-diameter prototype and more for larger prototypes. This is quite high in terms of present service missiles, but the trend seems to be toward higher exit velocity. It also appears that at lower water-exit velocities, water-exit perturbations will tend to increase. Therefore, if significant perturbations are observed at the water-exit velocities reported here, they are also likely to occur at lower velocities.

Two series of water-exit studies were run. The first was the missile without a probe to ascertain, insofar as it was possible, the water-exit perturbations that might occur with the typical and theoretically tractable hemisphere head. The second series was conducted on the missile with a probe to: (a) obtain more accurate and reliable data on missile water-exit behavior; (b) determine if the presence of the probe caused significant deviations in missile behavior from that observed without a probe; and (c) further develop the probe technique for future water exit studies.

A total of 71 launchings was made at trajectory angles of 15, 30, and 90 degrees with respect to the horizontal and air pressures of 0.1, 0.2, 0.3, 0.4, 0.5, 0.75, and 1.0 atmosphere absolute over the water surface. The 15 and 30 degree conditions were investigated both with and without the probe, and the 90 degree condition without a probe.

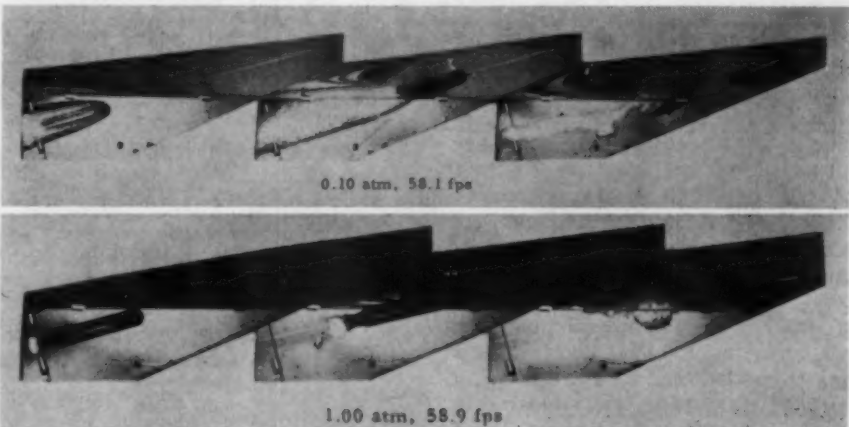
The accompanying photographs show clearly the perturbation of missile flight at water exit. Perturbation is dependent upon both underwater trajectory angle and atmospheric pressure above the water surface (i.e., degree of cavitation). The perturbation appears to be also influenced by the behavior of the cavity immediately prior to and during water exit. Thus, the cavity may provide a means of controlling the water-exit perturbation.

Addition of the probe to this missile nose caused an erratic cavity to form during some of the

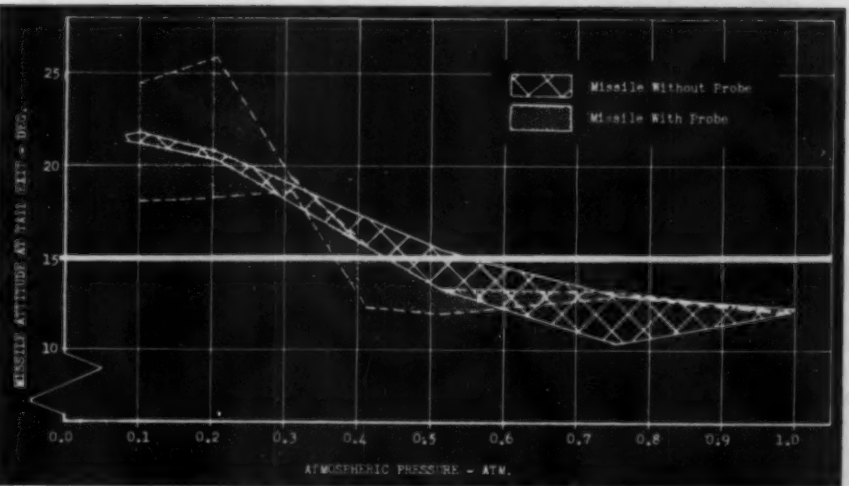
launchings, and altered water-exit behavior. In general, if an erratic cavity was formed, the water-exit perturbation was amplified. With a normal cavity, perturbation appears to be slightly suppressed by the presence of the probe. As might be expected, missile attitude is the parameter most sensitive to water-exit perturbations.

At trajectory angles of 15 to 30 degrees the maximum perturbation occurred at pressures of 0.1 and 0.2 atmosphere where the mis-

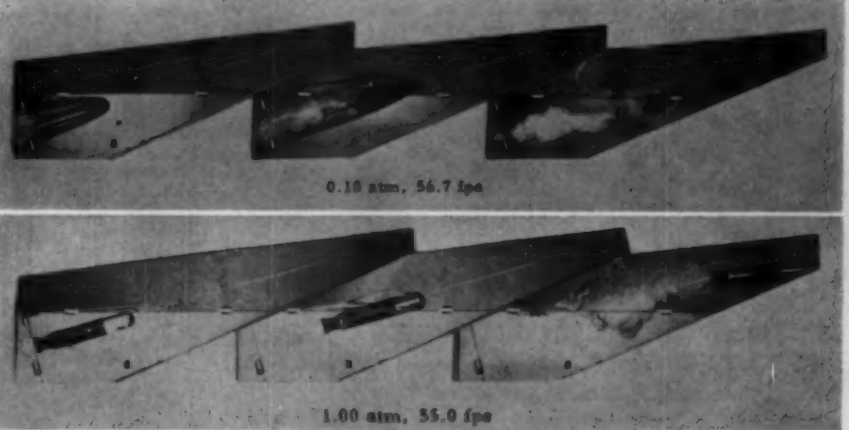
sile was in a fully developed cavity at the time of water exit. At 15 degrees the maximum perturbation occurred during launchings of the probe-nose missile; at 30 degrees the maximum perturbation occurred without a probe. For both trajectory angles the maximum perturbation was nose-up with respect to the underwater trajectory. Nose-down perturbations tended to occur under conditions of more fully-wetted flow. For vertical water exit (90 degrees) there did not



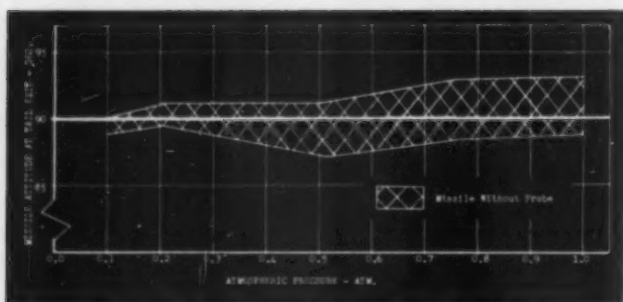
Missile with probe at 15° water exit angle.



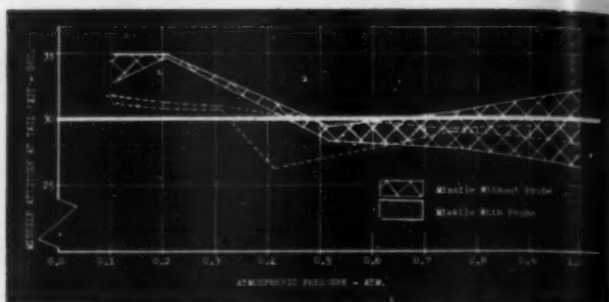
Exit attitude deviations from line of flight.



Missile without probe at 15° exit angle.



Perturbation record at 90° exit angle.



Perturbation record at 30° exit angle.

seem to be a trend in perturbation at any atmospheric pressure.

The observed scatter in missile attitude was significantly less at 0.1 atmosphere indicating more stability under fully-developed cavitation. At 0.2 atmosphere the perturbation was still small at the time of tail exit but became increasingly large during subsequent air flight, suggesting that further perturbations were caused by splash from the collapsing cavity. Some of the scatter at the higher air pressures may have been caused by transition from turbulent to laminar flow due to undesirably low water-exit velocities at these pressures.

A study was made to obtain consistent missile behavior with the probe in the missile nose. Streamlining the probe and reducing the surface tension of the water to approximately 28.4 dynes/cm increased the incidence of erratic cavities. A blunt probe made of slotted brass tubing of the same diameter as the regular probe was filled with nigrosine dye paste. During launching the dye streamed from the slot in the probe marking the flow over the missile nose. A zone of separation seemed to occur at the base of the probe. Fairing the probe to fill the separation zone improved the cavity greatly and indicated that the erratic cavity formation was being caused by disturbances in the flow introduced by separation of the probe boundary layer.

Tests showed that a promising technique for controlling the cavity of the probed missile is that of cutting an annular groove in the missile head where the cavity

**AIR PRESSURE OVER WATER SURFACE (Atm)<sup>b</sup>**

**CAVITATION NUMBER**

1.00	0.58
0.75	0.43
0.50	0.28
0.40	0.22
0.30	0.16
0.20	0.10
0.10	0.05

<sup>a</sup>For 60 fps missile velocity, the Froude number  $F = U / dg = 25.9$   
<sup>b</sup>One atmosphere is taken nominally to be 740 mm (29.14 inches) of mercury. Water vapor pressure (20°C) is taken into account in calculating the cavitation number.

**Cavitation Number at Water Surface for 60 fps Missile Velocity as a Function of Air Pressure Over the Water Surface<sup>a</sup>**

would normally tend to separate, i.e., where the hemisphere subtends an angle of about 78 degrees. This should mask any random perturbation introduced by the probe boundary layer and force regular separation of the cavity in the proper separation zone. Over one hundred launchings of the missile with the grooved, probe-head in further water-exit studies indicate the technique is successful.

**Conclusions** — Water-exit launchings were made with a 2-inch-diameter hemisphere-head missile at 60 fps nominal water-exit velocity, launching angles of 15, 30, and 90 degrees with respect to the horizontal and different degrees of cavitation ranging from nearly fully wetted flow to completely enveloping cavitation. The following

conclusions are drawn:

1. The missile is perturbed at water exit under all degrees of cavitation. The perturbations increase with decrease in trajectory angle and the maximum perturbations occur under conditions of fully developed cavitation. From these results it is inferred that water-exit perturbations will pose problems in service missile water-exit technology.
2. The addition of a nose probe altered the water-exit perturbations of the missile and sometimes caused erratic cavities to form. An annular groove cut in the missile nose at the zone of cavity separation stabilized the cavity and allowed consistent results to be obtained with the probe.\*

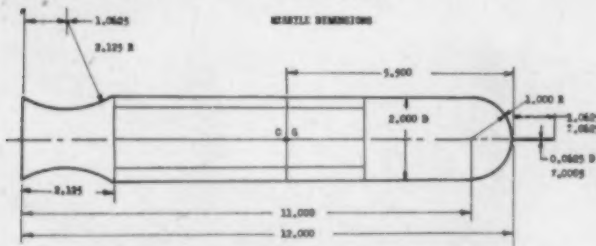
**PARAMETER**

**DIMENSION**

Diameter, in	2.000 + .000, -.001
Length <sup>a</sup> , in	12.004 ± .040
Mass, lb	1.272 — 1.329
Distance from CG to Nose <sup>a</sup> , in	5.50 — 5.60
Moment of Inertia <sup>a</sup> , lb-in <sup>2</sup>	18.19 — 18.21

<sup>a</sup>Length of probe not included. <sup>b</sup>About transverse axis through CG

**Missile Parameters**



Test missile diagram, including probe.



Test missile with cavity control groove.



Fleet Sonar School at Key West.

# training THE SONARMAN

by

Commander Harry L. Fitch, USN

Executive Officer

U. S. Navy Fleet Sonar School, Key West, Fla.

TASK GROUP ALFA STEAMS RELENTLESSLY toward the submarine contact area. The whole force alert for the submarine contact that will send them racing in for the kill. They are on watch in each of the destroyers and in the hovering helicopters. Without these men this force will never find the submerged enemy and track him to his death.

This is a heavy responsibility for a man to carry. What sort of man is this sonarman? Usually he is in his early twenties. Frequently he is still in his teens. He is above average in intelligence; his combined General Classification and arithmetic score must be 110. His hearing is acute and he must have a keen sense of pitch discrimination. He cannot have a hearing loss of more than 20 db at 512, 1024, and 2048 cps. For at least six months he has been intensively trained at Sonar School either in Key West or San Diego.

The psychological and hearing tests at the recruit training centers filter out the men with the basic requirements for sonarmen. They are shipped off to the sonar schools. Thirty-seven per cent of these

youngsters did not even finish high school.

About 20 per cent of these men fail the sonar course. This is too high a failure rate, but it is false security to send a man to the fleet who cannot do his job as a sonarman. A man is not dropped from the course until he has repeatedly failed exams and a review board thinks he doesn't stand a chance of successful completion.

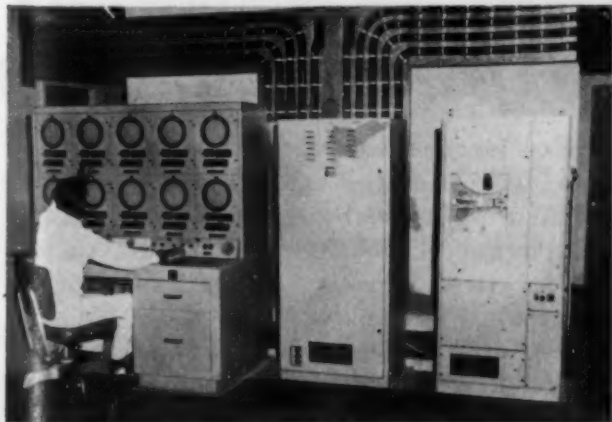
Because of the varied education background of the new students, the course starts off with a short math review. Essentially this is a review of high school algebra. This basic math is required for the electricity and electronics portion of the course that follows next.

Electricity and electronics seem beyond the comprehension of a distressingly large number of men. When will some genius invent electronic equipment that can be maintained by simple souls? Until he does all of the military services are faced with the same insoluble problem. The equipment grows more complex, but the men to maintain it remain basically static in native ability. The service technical schools

eagerly embrace new training concepts, but this forced draft education quickly yields a diminishing return. Heredity, home and high school produce the basic recruit. The service schools instill motivation and try to make up for lack of education, but there is a limit.

After nine weeks of electricity and electronics, the students then delve into the entrails of the sonar equipment. A few years back sonar equipment was maintained by electronic technicians. When it broke down the sonarman sat back and yelled for the technician to come fix it. There was not enough trained electronics men to go around, and the sonarman did not do a very good job of preventative maintenance. As a consequence, the equipment operated poorly or was completely down with embarrassing frequency. Once again the old truth became apparent; men responsible for the operation and performance of equipment will do a better job of maintaining it.

In studying the sonar equipment, the student first must understand the theory of propagation of sound in water; then, how the sonar equip-



Sonar Operator Target Classification Trainer—14E3, built by International Telephone & Telegraph Laboratories enables instructor to monitor ten trainees in isolated booth simultaneously.



Trainees constructing simple superheterodyne receiver. In background is the Philco electronic classroom demonstrator. Student sonarmen learn sonar maintenance as well as equipment operation.



U.S.S. Tullibee uses the world's largest, most powerful undersea sonar system, developed and now being produced by Raytheon.



World's smallest, lightest airborne dip sonar, developed and produced by Raytheon for U.S. Navy's A.S.W. operations.



Raytheon surface sonars are in world-wide service with the navies of the Free World.

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For over 60 years Raytheon's Submarine Signal Operation has led in advancing revolutionary hydrosonic concepts — beginning with development of the world's first underwater acoustic navigation equipment in 1901. From advanced systems to hydrophones, transducers, drivers, and amplifier components, Raytheon is today one of the United States Navy's chief developers and suppliers of airborne, surface and underwater ASW equipments that help meet the ever-growing threat in hy-

droospace for this nuclear age.

An example of this capability is the world's largest, most powerful undersea communications-detection system, now within the U.S. Navy's nuclear submarine Thresher. It is the first fully hull-integrated ASW sonar.

Under evaluation by the U.S. Navy is the world's smallest, lightest airborne dipped sonar.

Both were developed and are produced by Raytheon — typical achievements of Raytheon

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## *helps meet the threat in hydrospace*

Submarine Signal Operations ASW Center at Portsmouth, Rhode Island. Included among other significant achievements are advanced, fully transistorized sonar units for surface vessels of the Free World's Navies.

A unique defense complex, Submarine Signal Operation's ASW Center is the nation's first completely integrated industrial facility devoted exclusively to the design, development and production of Anti-Submarine Warfare equipment and systems. Its ca-

pability is further augmented by scientific and technical support from Raytheon's 34 plants and laboratories coast to coast.

FOR BROCHURE of Submarine Signal Operation's capabilities, write: Raytheon Company, Department 68, Lexington 73, Massachusetts, Attention: M. B. Curran.

FOR EMPLOYMENT OPPORTUNITIES, write: P. Alexander, Raytheon ASW Center, Box 360, Newport, Rhode Island.

**RAYTHEON COMPANY**

EQUIPMENT DIVISION

**RAYTHEON**

ment projects the sound into water. At this point the student begins specializing in the kind of equipment he will be assigned to when he graduates: airborne, submarine, or surface ship sonars. He spends seven weeks in learning his equipment.

After he has learned the theory and maintenance of his equipment comes the final pay-off—the actual operation of the sonar set. He spends two months learning to operate the equipment and to identify the sounds he hears. He becomes so familiar with the controls and dials that he doesn't need to look or even think about where those knobs are. He can concentrate on the sound and video presentation.

Finally when he hears that echo can he correctly identify it? The long range echoes are usually easy to identify because not many objects in the water give a good solid echo at that range. It is the close-in targets that are difficult to classify. So many things in the water will give an echo: Whales, wrecks, kelp, plankton, pinnacles, thermal gradients, fish, wakes, but each has a characteristic sound. Classification of that echo is the sonarman's primary job.

When he first hears the echo, he listens for the echo quality. Is it sharp and metallic or does it have a mushy sound? Wake and water phenomenon usually give a mushy echo, but the submarine hull gives a sharp metallic echo. Except when the sub is running away, then his wake will make the echo sound long and mushy. Fish give a long sometimes rippling echo, but whales give a short sharp echo.

The sonarman measures the width of his target on the video scope and listens very intently for doppler. If he can hear doppler, he can assume the target is moving. That eliminates inanimate targets such as kelp, wrecks, and pinnacles. Of course, a high speed submarine gives high doppler and usually cavitation. Whales will give him doppler, but no propeller noises. Just to complicate the problems, pinnacles, wrecks and other underwater objects will give some doppler effect if there is a current flowing.

As soon as he first hears the echo, the sonarman must say whether he thinks he has a submarine or non-submarine. He starts the classification process by his original observation. The final classification is made by the commanding officer of the ship after a lot of supporting information has been gathered in. How does the target track? Does it act like a submarine? Do support-



"Trouble-shooting" practice on fire control attack director Mk-5 (Librascope Div., General Precision, Inc.) is part of sonar course.

ing aircraft give MAD indications? Do other ships or helicopters hear the same echo and classify it the same way?

The young sonarman carries the burden of proof. His is the main evidence and much of it is dependent on his judgement. Quality of echo-sharp versus mushy sound is a matter of opinion. High versus low doppler, although this is a measureable quantity, in practice it is left to the judgement of the sonarman. Hearing and correctly judging these sounds is primarily a matter of long practice. Until about a year ago the only way a sonarman could be trained in hearing submarine echoes was to take him to sea and let him ping on a submarine. Taking one submarine and one destroyer to sea to train a sonarman was inordinately expensive. As a consequence of this lack of ping time, the ability of the sonarman to correctly classify sonar contacts dropped to a questionable proficiency.

Since that time significant improvement has been made in sonarman training by the 14-E Classification trainer built by the ITT Laboratories. This device is a series of units which have tape recording and playback components. They have both high fidelity sound and video signals. Actual runs at sea are reproduced on the trainer giving practically identical audio and visual information. The playback portions of the trainers are installed in shore installations (14-E-3) and on destroyer tenders (14-E-2). The recording units (14-E-1) are installed on ships making the runs for tape production. The 14-E trainers have been helpful in relieving the expense of providing ping services to sonar-

men. The early phases of classification are done on this trainer. Here he learns what the different sounds are and the basic manipulation of the equipment.

However, the device does not eliminate the need for sea services for the sonarman. This classification trainer can be compared to the Link Trainer; a pilot can do everything on a Link Trainer, but crash. Likewise, the 14 E trainer does nearly everything except provide a smart aggressive submarine opponent. Also transmission controls such as pulse length and mode selection cannot be used on the trainer.

The final two weeks of the sonarman's training is spent at sea pinging on a submarine target and learning the various jobs of the sonar team. By this time he considers himself a salty sailor and takes great pride in his work. All but a very few are successful in the final phase of the course. On graduation they proudly clutch their diplomas in their hands and march off to the fleet.

Everything possible is done to standardize the training and thus standardize the product, but people are all different. So the product is far from standard. Certainly they all possess roughly the same basic knowledge, but the application of that knowledge varies widely. Human Factors studies of sonarman show that they vary widely in attention span and ability to interpret the signals they hear.

It seems a shame to entrust the audio analysis of the sonar signal to so variable an instrument as people. But until some skilled engineer invents a computer to analyze this sound input, young sonarman will be doing it. ★

# Heel and Toe Watch

Here's a poser for those with a knack for the unusual in underwater systems. For the submarine of tomorrow Navy cites a need for an anti-aircraft weapon which will not give away the submerged vessel's location. Navy isn't specifying just what this system should look like, but suggests maybe something that would steal quietly to surface, search out target, and then launch missiles from there. Should this be a throw-away item—or wire guides and recoverable?

Important areas of research in underwater sound propagation are cited in a recent Defense Department report as: Low-frequency reliable acoustic path propagation at depths below 1,000 feet; long distance convergence-zone propagation and effect of bottom interference; shallow-water propagation with study of variables of frequency, sea clutter, bottom reflection, and time; target or ship noise and its modification over long distance; sea noise and its coherence from point to point; backward scatter and scatter out of the surface duct as functions of sea state, depth, and signal frequency; propagation velocity and absorption coefficient of bottom samples at ambient pressures up to about 20,000 psi.

Earth current technology is cited in same report as holding potential for communications with submerged submarines and development of means of long distance, non-acoustic detection and localization of submerged craft. Report states that principles have been proved; only sensitivity is in doubt.

Total of 130 Russians attended the recent 10th Pacific Science Congress. Representatives of the Soviet Embassy Naval Attaché's office also managed to get into the recent two-day symposium on coming needs in oceanographic instrumentation, sponsored by U.S. interagency committee on oceanography.

Before you think it's new, during World War II: The Japanese launched planes from submarines which bombed state of Washington in; Germans fired solid propellant rockets from submerged submarines; and Germans also developed and used deep depth torpedo (etc.) recovery devices using closed circuit television and remotely controlled manipulators, and demonstrated acoustical TV.

—Captain Nemo

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Coupling Coefficients:							
$K_p$ (planar or radial)	.30	.32	.31	.22	.20	.30	.45
$K_{12}$ (Driven perpendicular to Polarization)	.17	.19	.18	.13	.12	.30	.39
$K_{33}$ (Driven parallel to Polarization)	.45	.47	.46	.32	.30	.62	.56
Piezoelectric Constants:							
$d_{31} \times 10^{-12}$ coul/Newton	—56	—57	—55	—30	—24	—105	—110
$d_{32} \times 10^{-12}$ coul/Newton	142	145	140	90	79	240	255
$d_{33} \times 10^{-12}$ coul/Newton	—5.5	—6.0	—5.4	—5.7	—5.3	—11.0	—8.0
$g_{31} \times 10^{-3}$ volt meters/Newton	14.0	14.5	13.0	15.0	16.0	25.5	18.5
Dielectric Constant:							
@ 1 kc; 25° C	1200	1150	1100	600	500	1100	1700
Dissipation Factor:							
@ 1 kc; low field; 10 volts/mm	1.5%	1.5%	1.5%	1.5%	1.5%	.5%	1.2%
Density kg/m <sup>3</sup>	5500	5450	5450	5300	5250	7400	7800
Curie Point:	125°C	130°	120°C	140°C	145°C	345°C	340°C
Young's Modulus $\times 10^{10}$ N/M <sup>2</sup>	12.2	12.2	12.1	12.5	12.7	8.0	7.3
Frequency Constants:							
Disk - kc/inch	118	120	122	122	123	90	87
Cylinder - kc/inch	54	54	54	55	55	40	39
Bar - kc/inch	85	85	85	86	86	65	63
Suggested Maximum Operating Temperatures	79°C	80°C	75°C	88°C	94°C	285°C	280°C

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Circle Reply Card No. 13

# Speed of Sound Measurement

By F. J. Suellentrop, A. E. Brown, and Eric Rule  
Lockheed Missiles and Space Division, Palo Alto, California

THE NEED FOR A SIMPLE AND DIRECT METHOD OF measuring speed of sound in the ocean has recently been stressed in the literature<sup>1</sup>. At present, the speed of sound is usually derived indirectly by considering the speed to be a function of the temperature, pressure, and salinity in the ocean. Knowing or measuring the values of these parameters, speed of sound is determined using any one of a number<sup>2,3,4</sup> of empirically-derived formulae which contain up to six hours. This process involves considerable computation, and controversy exists as to which formula is most suitable.<sup>5</sup>

Where the need exists to establish speed-of-sound profiles rapidly or to monitor continuously the speed of sound, advantages of a direct-measuring instrument are obvious. Direct measurement is also to be preferred because the computational methods referred to above may not take account of all factors influencing the speed of sound.

An instrument capable of measuring the speed of sound in fluids has been developed at the National Bureau of Standards<sup>6</sup> and has recently been adopted for use in the ocean<sup>7</sup>. These devices use the well-known "sing-around" principle in which the frequency of an oscillator is governed by the transit time of a pulse of ultrasonic energy between two transducers separated by a fixed distance in the liquid in which the speed-of-sound propagation is to be measured.

An instrument developed by Lockheed Missiles and Space Division is based on the "sing-around" principle but uses different circuitry (fewer components) and a completely different packaging philosophy (great reduction in size) than earlier instruments. The improvement in packaging was made possible by a systematic study of the effect of extreme pressure on the characteristics of electronic circuit components such as transistors, resistors, inductors, and capacitors. System components are known to be stable to pressures up to 20,000 psi. Thus the electronic circuitry of the velocimeter can be encapsulated in standard epoxy potting compounds, instead of requiring bulky pressure housings.

The principle of operation of the instrument and the functions of the major electronic circuits are shown

in the accompanying diagram. The transmit-and-receive transducers are polarized discs of barium titanate ceramic backed with potting compound and operating in the thickness-resonant mode at about three mc/s. The five-transistor circuitry requires a 1.5-volt power supply from which it draws less than five milliamps. A regulated power supply with rechargeable battery can be submerged with the velocimeter.

The pulse generator sends out a pulse to the transmitter, causing it to emit a 3-mc/s acoustic pulse into the liquid. After traversing the distance  $L$  at the speed of sound  $c$ , the pulse is received at the receiver and converted into an electrical pulse which is amplified and used to trigger the pulse generator. This causes the pulses to sing around with a pulse repetition frequency being a function of the speed of sound.

The relation between velocity of sound in the liquid and output frequency of the instrument is not quite linear because of the finite time delay ( $t$ ) introduced by the electronic circuitry and piezoelectric transducers. Referring to the diagram, we have—

$$\text{Period of pulses} = \text{Transit time in liquid} + \text{Delay time in electronics} \\ = T + t$$

$$\text{Pulse repetition frequency} = f = \frac{1}{T + t}$$

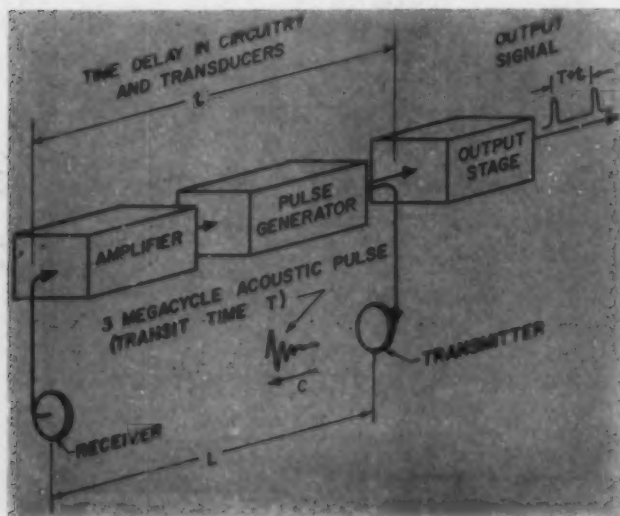
$$\text{Now, } T = \frac{L}{C}$$

$$f = \frac{1}{\frac{L}{C} + t} = \frac{C}{L} \left( 1 - \frac{Ct}{L} + \frac{C^2 t^2}{L^2} - \dots \right) \quad (1)$$

Typical values for velocimeters constructed so far are  $C = 1500$  m/sec,  $L = 0.1$  meters,  $t = 0.6$  microsec. so that the term of equation (1) involving squared quantities is negligible. The term  $C/L(t)$  in the equation leads to nonlinearity in the relation between  $f$  and  $C$  and becomes less important as  $t$  becomes smaller with respect to  $T$ . A calibration curve giving the relation between  $f$  and  $c$  is derived by measuring the output frequency of the instrument when immersed in distilled water at different temperatures in which the velocity of sound is known.<sup>8</sup> For this calibration to be valid under all oceanographic conditions it is necessary that the quantity  $t$  should not vary over the complete range of temperature and pressure encountered in the ocean, and quite elaborate test procedures are necessary to determine that this condition is fulfilled. The tests involve maintaining the transducers in a water bath in which temperature and pressure are constant while the electronic circuitry is subject to temperature and pressure changes over the range  $-5^\circ\text{C}$  to  $35^\circ\text{C}$  and 0-20,000 psi, respectively. Any change in output frequency is then undesirable and must be attributed to changes in the electronic circuitry. ★

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- 7) C. E. Tschiegg and E. E. Hays, J. Acoust. Soc. Am. 31, 7, 1038-1039 (1959).
- 8) M. Greenspan and C. E. Tschiegg, J. Research of National Bureau of Standards 59, 4, 249-254 (1957).



# new **u s t** products

## POWER

### Thermoelectric Cooler

Thermoelectric coolers capable of achieving  $-78^{\circ}\text{C}$  to  $-90^{\circ}\text{C}$  are among the electronic components being manufactured by Pesco Products Div., Borg-Warner.

The Pesco ICER is a compact unit consisting of an infrared detector cell mounted



on a four-stage cascaded thermo-electric cooler all installed within a vacuum enclosure. Heat rejected at the hot junction is dissipated by use of a Pesco fan and heat exchanger. Electrical power is supplied to the thermoelectric cascade with a single pair of leads.

These micro refrigerators can also be used for cooling diodes, crystals, transistors and components of masers, and parametric amplifiers.

Circle Reply Card No. 200

### Power Converter

The Hoover Co. has announced a line of power converters, ideally suited for applications where the power source is a thermoelectric generator, fuel cell or low voltage battery. Efficiency of the new unit is greater than 75 per cent. A wide range of input and output parameters is available.

Circle Reply Card No. 201

## COMMUNICATIONS

### Undersea TV

Packard Bell Electronics has produced a high resolution closed circuit TV system designed specifically for military applications



ranging from ASW to missile firing. The camera is enclosed in an environmental type container, eliminating the need for special housing.

Circle Reply Card No. 202

### VLF Receiver

Develco has developed a six-channel VLF

receiving system covering the 10 to 30 kc/s frequency range. Complete system includes antenna, remote pre-amp and broadband filter, and six separate plug-in channel units. Can be used for field strength measurements, underwater propagation measurements, direction of arrival studies, whistler mode studies, and monitoring of VLF signals.

Circle Reply Card No. 203

## INSTRUMENTATION

### Magnetic Sensors

Two new Hall-Effect magnetic sensing devices—The Transverse Field and Axial Field "Hall-Paks"—have been produced by F. W. Bell, Inc. Both units are non-inductive and

exhibit low noise output. Operating temperature range is  $-40^{\circ}\text{C}$  to  $+100^{\circ}\text{C}$  and the devices are designed for continuous operation at  $85^{\circ}$ .

Circle Reply Card No. 204

### Frequency Standard

A Rubidium Frequency Standard from Clauser Technology Corp. is accurate to 5 parts in  $10^{10}$  and has a long term stability of 2 parts in  $10^{10}$ . The portable unit is used for primary frequency and/or time standard in communications, navigation and tracking.

Circle Reply Card No. 205

### Stress Measure

From Unilectron comes "MIDAS" (Miniature Data Acquisition System), a real-time FM/FM, multi-channel telemetry system capable of sensing and transmitting heartbeat, pressure, strain, acceleration, etc. Industrial applications include measuring rotating

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Circle Reply Card No. 14

## ASW ENGINEERS

Several immediate, high-level assignments are currently available for qualified Anti-Submarine Warfare Engineers in Hughes-Fullerton's new Overseas Warfare Department. These assignments are concerned with design and development of advanced underwater intelligence systems for ASW applications. Urgent requirements currently exist for:

**Information Theory Specialists:** Experienced and interested in: ■ Statistical Modeling of Noise and Signal Fields. ■ Application of Statistical Decision Theory to Advanced Information Systems ■ Mathematical Studies of Signal Noise Discrimination.

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**Systems Synthesists:** Unusually creative engineers who can reduce vague requirements to useful technical terms. ■ Apply imagination leading to new approaches and new concepts. ■ Describe engineering implementations to meet the system requirements. ■ Are qualified in information processing systems using sampling and correlation techniques; broad studies of the present and future physical and military environment of the submarine.

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Circle Reply Card No. 206

### Salinity Indicator

A modular-design Salinity Indicator providing instantaneous measurement and correlated alarm or control is being marketed by Industrial Instruments. The unit is designed to indicate amount of dissolved salts in water and steam.

Circle Reply Card No. 207

### Pan and Tilt

Operating to 1,000 feet, Ward Associates' submersible pan and tilt permits remote controlled underwater position with 360° of pan and 90° tilt. Other systems are available for operation at any depth.

Circle Reply Card No. 208

### Transducers

Dynamic Measurements Co., announces a new line of universal linear displacement transducers. Operating on the differential transformer principle, the models are designed for optimum performance at 400 cycles, but can be used at frequencies from 50 to 6000 cps.

Circle Reply Card No. 209

### CONTROLS

#### "Choppers"

A line of low impedance photoelectric modulators, or "choppers", is offered by Cambridge Electronics Corp. The units are designed to match circuit impedances of 1.5 K ohms, and offer either SPST or DPST switching action.

Circle Reply Card No. 210

### Motor Speed Control

Instrument Development Labs has made

available a transistorized modular attachment to its family of Rotary Switches for precision control of the 28 volt dc input. Motor speeds can be held to better than 2 per cent regulation over the temperature range of -55° to +100°C.

Circle Reply Card No. 211

### Pressure Regulator

An ocean floor pressure regulator designed for ASW applications has been introduced by Marotta Valve Corp. The model RV-23AA protects electronic equipment against pressures encountered at various ocean depths. Operates with inlet gas pressure up to 5000 psi at depths up to 10,000 feet.

Circle Reply Card No. 212

### SOLID STATE

#### Power Transistors

A series of eight germanium power transistors with junction temperature ratings of 110°C and maximum power dissipation ratings of 170 watts has been announced by Motorola Semiconductor Products, Inc.

Circle Reply Card No. 213

#### Zener Regulators

A complete range of 1-watt zener regulators is being made by North American Electronics, Inc. Voltages range from 2.8 to 200 volts, and they can carry up to 150 ma test current.

Circle Reply Card No. 214

#### Guard Ring Detector

Solid State Radiations announces a unique low noise guard ring used for the detection of charged particles in or out of a vacuum. The guard rings can be used in both one and two dimensional arrays.

Circle Reply Card No. 215

## "NUKES" need RELIABILITY too



Nuclear submarines have launched whole new systems of anti-submarine warfare. Powerful new low-frequency sonar requires the most delicately complicated listening apparatus yet devised. Project Artemis is expected to do for the oceans what the DEW line now does for the North American continent.

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Circle Reply Card No. 16

# u s i literature

## Sub-System Packaging

Catalog D/supplement, from Zero Manufacturing, lists off-the-shelf sizes of containers required for sub-system packaging for POLARIS programs. Pressure equalizers, humidity indicators and spring-loaded latches are standard equipment.

Circle Reply Card No. 216

## Humidity Systems

An 8-page catalog, published by HYGRODYNAMICS, INC., lists complete line of basic hygrometer instrumentation and systems for various applications, such as detecting, measuring, recording and controlling relative humidity.

Circle Reply Card No. 217

## Microcircuitry

Varo Inc., is offering a catalog on its microcircuitry devices now available as standard circuits. Descriptive data on digital, computer, control and audio frequency circuits are featured. Photographs, complete specifications and prices also included.

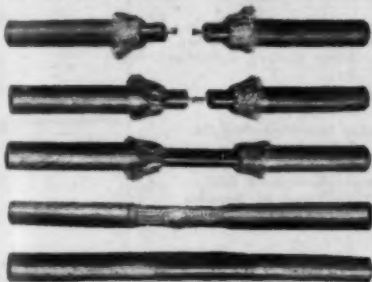
Circle Reply Card No. 218

## Battery-Substitute

Dynage, Inc. has prepared technical data sheets on a new recorder bridge voltage supply known as BATT-SUB. The unit operates from normal line voltage and delivers a constant DC voltage to the measuring circuit bridge.

Circle Reply Card No. 219

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Circle Reply Card No. 18

## Water Conversion

"Progress in Water Conversion" bulletin GED-4135, reports on the current status of General Electric's new thin-film water distillation process for salt and brackish waters and indicates applications in industrial and marine areas.

Circle Reply Card No. 220

## Sensors

Designers for Industry has prepared a Progress Report on optical, infrared, magnetic, electromagnetic and nuclear devices used for inspection, detection, measuring and controlling.

Circle Reply Card No. 221

## Cable Assemblies

Electro-Mechanics, Inc. published a brochure explaining their facilities to assemble conductors into tailored cable with Neo-

prene or Polyvinyl Chloride jackets for waterproof protection.

Circle Reply Card No. 222

## NMR-EPR Catalog

Nuclear Magnetic Resonance and Electron Paramagnetic Resonance spectrometer systems and components are covered in Varian Associates' new catalog. It contains a brief description on the technique of NMR and EPR spectroscopy.

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## Thermocouples

Standard thermocouple models with a response time less than 10-micro-seconds to transient flow are described in a catalog released by Nanmac Corp. Pressure range to cover 50,000 psi, velocity range over 6,000 fps.

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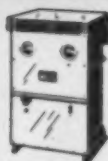
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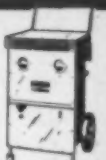
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## u s t people

Dr. Charles L. Bretschneider has been appointed to head the Wash., D.C., office of National Engineering Science Co., where he will be responsible for research programs in oceanography and hydrodynamics. He was formerly Chief of the Oceanographic Branch, Research Div. of the Army Corps of Engineers' Beach Erosion Board.

Dr. Sidney K. Shear has been named Director of Research of the Naval Warfare Analysis Group, division of the Operations Evaluation Group of M.I.T. OEG is the successor to the ASW Operations Research Group, the first formal military operations research organization in this country.

Appointment of Dr. Grant S. Bennett as Chief Scientist—Acoustics for Chrysler Corp.'s Missile Div. was recently announced. Backed by more than 20 years experience in underwater sound and ultrasonics, Dr. Bennett will direct activities in underwater acoustics R&D.

The Operations Evaluation Group of M.I.T. has added four members to its research staff: Dr. Robert L. Hubbard—physicist, Dr. Edgar R. Terry—Mathematician, Marc A. Nerenstone—ceramics engineer, and Vernon E. Palmour—operations analyst. The group conducts operations analysis in submarine and anti-submarine warfare for Office of the Chief of Naval Operations.

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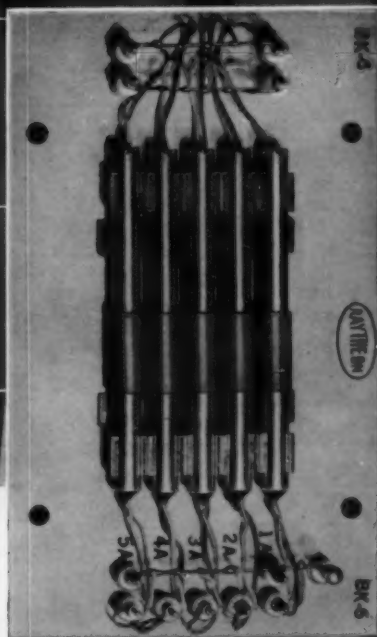
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